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MINISTRY OF THE ENVIRONMENT

BRITISH COLUMBIA

SALMON RIVER STUDY

LOW FLOW WATER RESOURCE USE

Water Investigations Branch

Date: September, 1976

File: 0273896-5B
0322531

ABSTRACT

The Salmon River basin of the Shuswap Lake region experiences a conflict in its water resource use during the summer low flow period between irrigation diversions and salmon reproduction requirements. An intensive study of the Salmon River has been conducted by the British Columbia Water Investigations (W.I.B.) and Fish and Wildlife (F.W.B.) Branches. Data collection commenced in 1974 and the study findings are assembled in this W.I.B. report which assesses the water resources by defining the surface flow, groundwater flow, licensed water withdrawals and fishery requirements within the total Salmon River regime. The objective of the study is to develop a meaningful water resource management plan.

The Salmon River, approximately 90 miles long, has a complex flow regime due to a highly permeable valley floor of unconsolidated surficial deposits and extensive irrigation withdrawals. Two hydrologic zones were defined by a water balance analysis for the whole basin, a low runoff southwestern zone and a moderate runoff northeastern zone. Temperature, precipitation and runoff were defined for each zone using all available hydrologic data. A supplementary hydrometric network was established to monitor tributary basin runoff, the variability of the mainstem channel flow and representative salmon spawning sites. The groundwater regime was described from groundwater well observations, regional geological mapping and comparison of streamflow records of mainstem hydrometric stations. Groundwater variation and return flow from irrigation were defined from a test site of a series of observation wells and a pump test well located on a representative farmfield adjacent to the river. Irrigation water use was determined from water license data with individual licensed quantities listed in an upstream to downstream order and subtotalled at each hydrometric station along the Salmon River. The mainstem stream flow regime was analysed for the 1975 and average summer low flow critical periods in which the water use components were related to expected and observed surface flow. Streamflow data was obtained from hydrometric stations and special mainstem channel streamflow surveys. It appears that approximately between one-third and one-half of the water available in the Salmon River in the low flow months (August and

September, 1975) is used by licensed water diversions. In average summer low flow months minimum salmon reproduction requirements (depth and velocities) are surpassed by approximately 30 cfs for a channel distance from one to 14 miles from the mouth in the non-spawning reach but are deficient from 15 to 39 miles, in the spawning reach. It was estimated that up to approximately 7800 acre-feet of water (based on 32 cfs withdrawal during August) is available in the water surplus reach during average flow conditions for future restricted water licenses. However, irrigation diversions up to 2300 acre-feet should be conditionally licensed (available 90% of the time) until more data is collected and actual field experience is gained to ascertain the fishery requirement criteria and to revise the water surplus estimates. Return flow is not accounted for since a perfectly efficient irrigation system is assumed. Critical hydraulic characteristics (e.g., cross-sections, depths and velocities) were defined for seven streamflow gauges at or near representative salmon spawning sites. A regulation program is recommended where low flows would be observed by the F.W.B. or a water bailiff who would notify the Water Rights Branch, the water license regulatory agency, to curtail water withdrawals for the required amounts and duration to preserve salmon reproduction requirements. The W.I.B. would maintain stage-discharge relationships at the fishery stations for regulation and data upgrading purposes. Of the supplementary hydrometric network some stations will be discontinued while another is proposed along with some groundwater wells in the Westwold aquifer for further hydrologic study and monitoring purposes.

Other recommendations which would enhance water resources management in the Salmon River basin include the following: review and conduct a field survey of licensed water withdrawals to determine or estimate the actual quantity withdrawn, cancel unused licenses, redefine current licenses to total seasonal quantities and monthly rates of withdrawals based on irrigation needs, establish a licensing system for subsurface water useage similar to surface water licensing, meter surface and subsurface irrigation withdrawals, implement a streamside vegetation program proposed by the F.W.B. to reduce high water temperatures which are hazardous to fish reproduction, develop headwater storage on Bolean Creek and Spa Lake, review the engineering feasibility of corrective action for channel restrictions for fish access and conduct an economic analysis of the Salmon River basin for a water use plan which would result in efficient and equitable distribution of the water resource.

PREFACE

Historically the Salmon River of the Shuswap Lake region has been the object of vital concern to irrigation and fishery interests, two major conflicting users of a very limited water resource during the low flow period. This concern was first highlighted in 1954 in a report by the Canada Department of Fisheries in response to continuous local irrigation water demand and a major irrigation diversion proposal. As more water licenses were applied for on the mainstem of the Salmon River, the British Columbia Commercial Fisheries Branch requested in 1971 and again in 1974, of the Water Rights Branch (W.R.B.) to restrict and regulate their water licenses in order to maintain sufficient minimum flows to preserve spawning capabilities. A preliminary hydrologic study was made by the Water Investigations Branch (W.I.B.) in 1971 at the request of the W.R.B. In March, 1974 the British Columbia Fish and Wildlife Branch (F.W.B.) suggested that an intensive study of the Salmon River regime be carried out jointly with the W.I.B. with the object of instituting a meaningful water resource management plan. The resulting overall study and data collection consisted of three related parts: surface water definition and licensed water use coordinated by the author (W.I.B.), fishery reproduction requirements (Reference 18) coordinated by S. J. MacDonald (F.W.B.) and groundwater definition (References 2 and 3) coordinated by E. G. Le Breton (W.I.B.).

For this study a series of mainstem hydrometric gauges, fishery stations and a groundwater experimental site were established in 1974 to compile data for a two-year study. Using this and other historical data and references this report attempts to assess the Salmon River water resource by defining quantitatively the respective roles that surface flow, groundwater flow, licensed water withdrawals and fishery requirements play individually and collectively within the total river basin by way of a low flow regime analysis.

This report presents all the detailed surface water studies and amalgamates all the other study findings to develop a water resource management plan for the Salmon River basin. The format of the report allows the reader to obtain a general overview of the study by focussing on the Introduction and Conclusions, the first and last sections. The internal sections are somewhat detailed and can be read by those interested or specializing in the relevant fields that are covered by each corresponding section. The appendices present the compiled data relating to the study as well as a proposal for a water resource economic study for the Salmon River basin.

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1. INTRODUCTION

The Salmon River drains an area of 557 square miles of the interior of British Columbia tributary to the South Thompson River basin and enters Shuswap Lake at the city of Salmon Arm. The river flows along one main gently winding valley which experiences a mild and relatively dry climate. The water resource of the Salmon River basin historically has been the basis of two important industries, agriculture and fisheries. The fertile valley supports a substantial agricultural community which depends on the limited water resource for irrigation during the summer months. Irrigation demand for Salmon River water even extended to the neighbouring Okanagan Valley when in 1947 a major irrigation diversion was proposed to Grandview Flats (Reference 7) but was never implemented. Also, the Salmon River has in the past supported substantial salmon runs which were at times limited by low flow conditions in the summer and fall months. As the farming industry developed and water demand increased, a conflict over the natural water resource was inevitable and with time an impasse was reached that required resolution.

Concerned federal and provincial fishery agencies urged the Water Rights Branch to restrict and regulate their water licenses in the Salmon River basin in order to preserve the fishery. A Canada Department of Fisheries report (Reference 11) in 1954 outlined the historical salmon spawning runs in the Salmon River and suggested that maximum rates of irrigation water withdrawals be stipulated on water licenses for the purpose of maintaining minimum flows to preserve the salmon fishery. Subsequent correspondence by the provincial Commerical Fisheries Branch requested licensing regulation and restrictions on new water licenses.

The provincial Water Rights Branch (W.R.B.) published a report in 1953 (Reference 13) which described the hydrologic regime of the Salmon River basin and attempted to define the amount of available water and its feasibility for irrigation purposes. Using available streamflow data, local groundwater well data, geological mapping, and an extensive field investigation the report described the Salmon River regime and roughly quantified streamflow and groundwater components. Howdver, no attempt was made to relate irrigation and fishery use components.

This report outlines the intensive study of the Salmon River regime by the Water Investigations Branch (W.I.B.) and the Fish and Wildlife Branch (F.W.B.). The study which commenced with data collection in 1974 assesses the water resources of the Salmon River by defining quantitatively the surface flow, groundwater flow, licensed water withdrawals and fishery requirements within the total river regime of the basin. The objective is to institute a meaningful water resource management plan.

The Salmon River has a complex flow regime due to a highly permeable valley floor of unconsolidated surficial deposits. The mainstem surface flow varies considerably along its 90 mile length and does not consistently increase with tributary drainage area. The basin features two hydrologic zones, a low runoff southwestern zone and a moderate runoff northeastern zone. As historical streamflow data within the Salmon River drainage is sparse, a regional water balance model using all applicable hydrometeorologic data was utilized to define mean monthly temperature, precipitation, evapotranspiration and runoff in both zones. A supplementary hydrometric network was established for this study to monitor tributary basin runoff and the variability of the mainstem channel flow. The measured tributary runoff was also used to estimate expected mainstem runoff as an alternate method to the above water balance runoff estimates. Fishery hydrometric stations were established at seven representative salmon spawning sites between Falkland and Salmon Arm. Hydraulic characteristics at these stations were surveyed and referenced to adjacent staff gauges to define critical water level and flow conditions for spawning purposes. During the low flow period a mainstem channel streamflow survey was carried out at the hydrometric stations, fishery stations and at designated miscellaneous sites which measured signficant flow changes.

The basin geology and groundwater regime were described from groundwater well observations, regional geological mapping and comparison of streamflow records of mainstem hydrometric stations. A groundwater test site was established (by the Groundwater Section, W.I.B.) consisting of a series of observation wells and a pump test well located on a representative farm field adjacent to the river. The objective of this program (References 2 and 3) was to determine the groundwater variation and return flow from irrigation. Groundwater flow estimates were also made for Westwold and Glenemma. The effect of groundwater well withdrawals on the total mainstem flow regime is discussed.

Irrigation water use was determined from water license data within the Salmon River watershed. Individual licensed quantities were listed in an upstream to downstream order and subtotalled at each hydrometric station so that a direct comparison between licensed withdrawal and channel flow could be made.

The period of greatest demand on the water resource is during the low flow season. The low flow regime of the Salmon River was analyzed by defining the critical months and the quantities of conflicting water use in relation to surface and subsurface flow of the river system. Required flow conditions for salmon reproduction were determined and minimum depths and velocities were defined at the seven fishery hydrometric stations. A water regulation program is proposed whereby W.I.B. would maintain stage-discharge curves at the fishery stations, F.W.B. (or a water bailiff) would monitor critical low flows and W.R.B. would curtail, as required, any new irrigation diversions (and old, if necessary to maintain the required flow conditions for salmon reproduction) for which additional water appears to be available during average conditions. The F.W.B. have also identified adversely high water temperature conditions for salmonid reproduction in exposed reaches of the Salmon River and have proposed a streamside vegetation program.

Other water use considerations relevant in discussing the Salmon River system are briefly considered and recommendations are made to evaluate their significance. Storage potentials in the Salmon River tributaries are presented based on previous surveys and reports. Corrective action is suggested for channel restrictions to fish access in at least two reaches of the mainstem Salmon River. As a supplement to the study an economic analysis is proposed for an ideal water management plan which could result in an efficient and equitable distribution of the water resource.

2. SALMON RIVER BASIN

The Salmon River drains a basin of 557 square miles from its source in the Douglas Plateau to its mouth on Shuswap Lake at Salmon Arm (Figure 3.1). From an elevation of 6000 feet at Bouleau Mountain the river flows west to Salmon Lake, northwest to Westwold, east to Glenemma and then north to Shuswap Lake for a total distance of 92 miles. The Salmon River valley, narrow through its upper reaches, widens to approximately two miles at Westwold, narrows to about 1000 feet between Falkland and Haines Creek and then gradually widens out again to approximately two miles at Salmon Arm. The area-elevation curve for the Salmon River at Salmon Arm (Appendix A) shows a median basin elevation* of approximately 3700 feet but flattens out to show a large valley bottom. The channel profile curve (Figure 5.1) also shows a flat slope (0.3%) in the last 60 miles of river which decreases from 2200 to 1100 feet elevation.

The Salmon River lies in an almost continuous belt of unconsolidated deposits overlying volcanic and metamorphic rock. The bedrock has low porosity and permeability and hence minor quantities of groundwater. The surficial geology of the basin consists of till, clay, silt, sand and gravel ranging, in order, from low to high porosity and permeability where the signicant groundwater occurs. Detailed geology and groundwater regime descriptions of the basin are presented in Section 6.

*On an area-elevation curve one half of the drainage area lies above and one half lies below the median basin elevation.

The Salmon River basin experiences a moderate climate influenced predominantly by westerly frontal storms. The Coast Mountains exhaust much of the moisture from the air masses to create an extensive rainshadow over the Interior Plateau. The Monashee Mountains east of the basin again induce a marked increase in precipitation. The western portion of the Salmon basin in the plateau region receives a mean annual precipitation* of approximately 20 inches while the eastern portion in the Shuswap Highland receives approximately 35 inches. Westwold in the west zone at elevation 2020 feet records a mean annual precipitation of 12 inches while Salmon Arm in the east zone at 1660 feet records 21 inches for the 1960-1969 period.

Temperature variation on the other hand is relatively uniform in the whole Salmon River basin since it is not affected orographically to the same degree as precipitation. Temperature depends more on large-scale air mass characteristics. Mean annual temperature for the 1960-1969 period at the median basin elevation is 39°F. The annual means for Westwold and Salmon Arm are 43° and 46°F, respectively.

Most streamflow in the Salmon River basin originates from depletion of the winter snowpack at high elevations. Relatively high runoff in May and June, a rapid recession during July and base flow in the remaining months, result in a mean annual runoff of some 6 to 7 inches over the whole basin (Table 4.1).

The agricultural industry of the Salmon River valley consists primarily of hay crop (alfalfa) farming with some stock (beef) farms in the upper half of the basin (above Falkland). Hay crop, silage corn, dairy and stock (beef) farming (in that order of importance) is carried out in the lower half of the basin. Fertilizing practises, mostly manure applications and moderate commercial fertilizers, are employed for hay crops and moderate to heavy fertilizers, for corn crops. These practises affect water quality locally but probably not signficantly, on a regional basis.† There is no industry known to affect

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* Precipitation means, based on the 1960-1969 period analyzed in Section 3.1, are extracted from precipitation-elevation curves using the median basin elevation.

† Agricultural descriptions are based on personal communications with E. L. Berry, District Agriculturist, Ministry of Agriculture, Salmon Arm, B.C.

water quality in the Salmon River with only 0.1 cfs water licensed for industrial use. No waste water effluent enters the channel. The chemical water quality of the Salmon River is above drinking water standards. However, some reaches of the river many not be suitable by bacterialogical standards due to high coliform levels whose source is suspected to be fecal material from cattle in the vicinity of the river channel.*

3. HYDROLOGIC DATA

3.1 Meteorologic Data

Within the two hydrologic zones covering the Salmon River region there are nine meteorologic stations with adequate historic data. None are above 2300 feet elevation; two fall within the Salmon River watershed, one in each of the two zones. The stations are located on the valley floor where easy accessibility and availability of observers dictated their installation. However, higher precipitation elevation stations are required not only for an accurate basin precipitation definition but also for runoff definition.

Temperature and precipitation data summaries for a ten-year study period (1960-1969) were obtained from Reference 9, a study of the neighbouring Okanagan basin. These data summaries proved useful for this study since missing portions of the record had been estimated, means were adjusted to the standard 1960-1969 period and it enabled the use of some stations which were inactive after 1969. Table 3.1 lists the temperature and precipitation means for the 1960-1969 period and the 1974 and 1975 water year periods (November to October). Figure 3.1 shows station locations.

3.2 Snow Course Data

Whereas meteorologic stations are generally confined to valley floor elevations, snow courses are usually located in the higher runoff

* Water quality descriptions are based on personal communications with J. E. Bryan, Pollution Control Branch, Vernon, B.C.

Table 3.1 METEOROLOGIC DATA

Plot No.	Station	Elevation (ft.)	Annual Temperature (°F) Mean 1960-69	April-March 1973-74	April-March 1974-75	Seasonal Precipitation (in.) November-March Mean 1960-69	November-March 1973-74	November-March 1974-75	April-October Mean 1960-69	April-October 1974	April-October 1975
1	Armstrong	1187	45.1			8.4			9.8		
		1230		46.1	44.3		9.31	11.81		6.14	8.44
2	Chase	1165	46.3			7.3			8.6		
4	Falkland S.R.	1500	44.9	45.0	43.3	8.3	11.57	13.62	8.7	5.80	8.71
6	Kamloops	1243	48.0	49.3	47.2	4.0	3.65	6.98	5.9	2.81	4.11
12	Monte Lake	2242				6.7			8.3		
12'	Monte Lk. P.V.	3000		41.1	38.9		7.99	10.64		7.43	9.12
14	Salmon Arm	1660	46.3	46.4	44.8	9.5	12.96	14.53	11.1	7.36	10.24
15	Salmon Arm 2	1300	46.1	46.6	45.0	9.7	13.84	15.92	10.3	7.90	9.66
20	Tappen F.R.	1860	46.1			11.4			11.6		
25	Westwold	2020	43.2	43.7	41.3	4.8	4.86	8.22	7.4	5.03	7.05
	McCulloch	4100	37.4	37.1	35.1	12.4	19.43	16.56	12.8	9.38	11.50
	Mt. Lolo Kamloops	5700	35.1	34.7	32.4	8.6	9.47	8.75	12.2	8.47	9.07

Table 3.2 SNOW COURSE DATA

Plot No.	Station	Elevation (ft.)	April 1st Snow Water Equivalent (in.) Mean 1960-69	1974	1975
31	Bouleau Creek	5000	11.0	16.9	17.9
130	Enderby	6250	33.6	50.2	47.3
85	Lac Le Jeune	4500	5.0	6.5	7.7

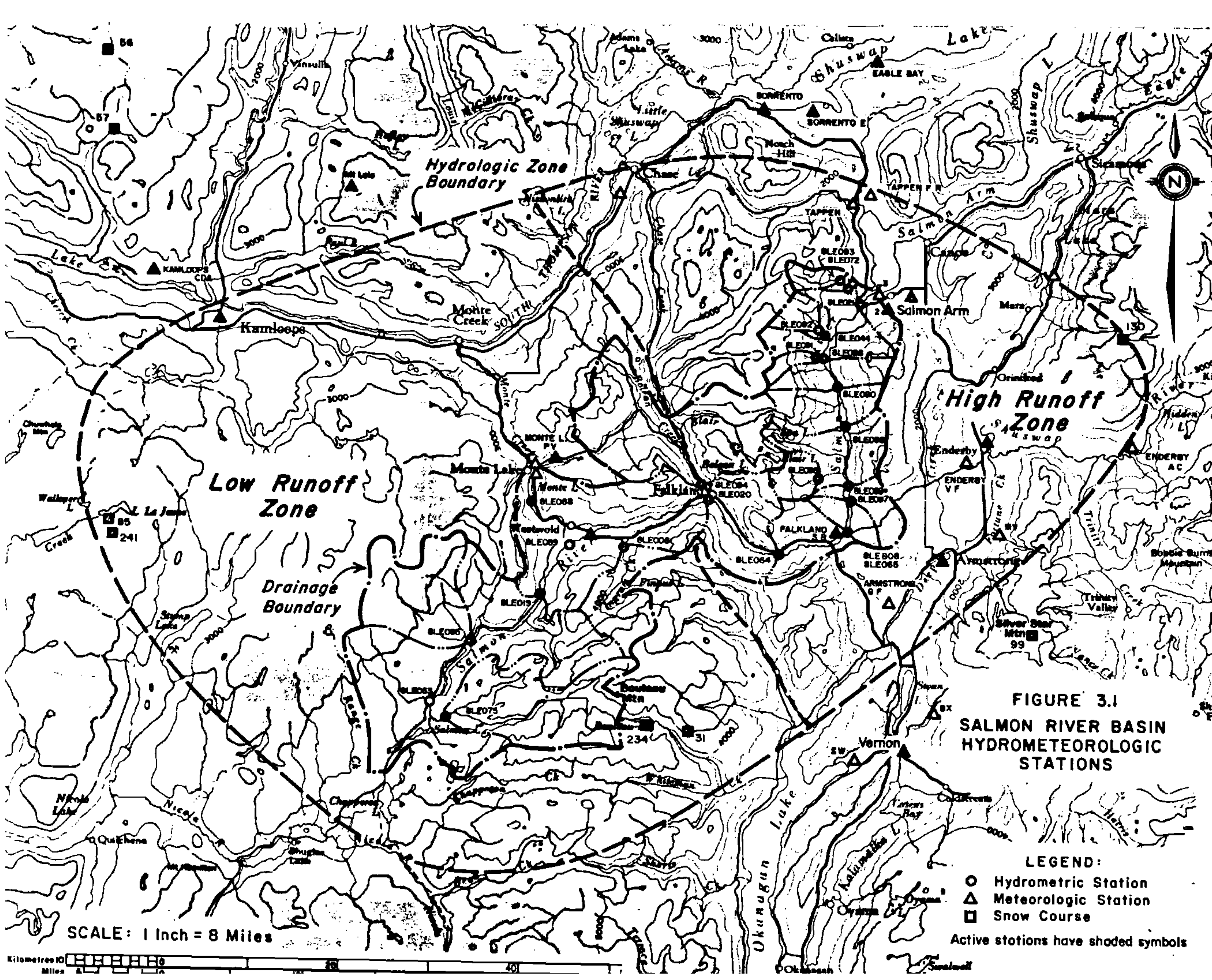

FIGURE 3.1
SALMON RIVER BASIN HYDROMETEOROLOGIC STATIONS

producing mountain regions. There are only three snow courses with sufficient records for the 1960-1969 standard period within the hydrologic zones of the Salmon River region but none within the watershed. All of these are above the median basin elevation and provide vital information for the extension of the precipitation-elevation relationships of Section 4. April 1st snow water equivalent for 1960-1969 (mean), 1974 and 1975 are presented in Table 3.2 and station locations are shown in Figure 3.1.

3.3 Hydrometric Data

Hydrometric records have been collected at a number of locations within the Salmon River basin. However, most of these are seasonal, collected for irrigation and water supply purposes (see Figure 3.1 and Table 3.3). For hydrologic purposes continuous flow data are desirable but seasonal data are also useful as they include approximately three-quarters of the annual flow by volume. When fisheries concern for low flows became apparent the Salmon River gauge at Falkland was converted to continuous operation in 1951. In 1966 the gauges above Salmon Lake (8LE075), on Gordon Creek (8LE044) and Palmer Creek (8LE072) were established with continuous operation. Most of the hydrometric data are of short duration and have limited concurrent record.

In order to utilize all the hydrometric records on a comparable basis, a long-term station is required that covers the periods of all hydrometric records. Suitable for this purpose were the combined records (1911 to 1973) of the South Thompson River at Chase (8LE031) and at Monte Creek (8LE069) gauges which include the Salmon River drainage. However, since this drainage is only 9% of the area of the South Thompson River drainage (8LE069) and its mean annual flow only 1.5% of the latter, a stronger basis of comparison is desirable. Simple correlations were made between the South Thompson River and Salmon River hydrometric records. Example correlation coefficients of 0.94 and 0.97 for seasonal records of 8LE021 and 8LE019 and 0.96 for annual records of 8LE075 demonstrate a very similar hydrologic pattern between the Salmon and South Thompson River basins. The short-term seasonal mean of each Salmon River basin hydrometric record was adjusted to a long-term mean annual runoff by comparing the common short-term data of both stations to the long-term South Thompson River station (1911-1973). Relevant hydrometric data and adjusted means for the 1911-1973 and 1960-1969 periods are listed in Table 3.3. Hydrometric data summaries were obtained from Reference 1.

3.4 Supplementary Hydrometric Network

During the initial study investigation it was recognized that the hydrometric data of the Salmon River basin was inadequate to meet the objectives of defining the low flow river regime. Since the mainstem river flow exhibited abnormal variation along its total reach, six new Salmon River gauges were established in the spring of 1974 at suitable locations. In addition, four tributary gauges were established above the permeable valley floor to sample the regional tributary hydrology. The geology and the probable groundwater conditions affecting each tributary stream gauging site were evaluated during reconnaissance and final site selection was made to minimize groundwater underflow. In total, 11 mainstem and 8 tributary gauges are presently active in the Salmon River watershed. Gauge locations are given in Figure 3.1 with types and periods of record in Table 3.4. Table 3.5 lists observed tributary runoff data for the 1975 water year (November to October).

3.5 Fishery Spawning Stations

Seven salmon spawning reaches on the Salmon River between the railway bridge above Falkland and Silver Creek were designated as fisheries stations by the Fish and Wildlife Branch. These stations are designed to monitor hydraulic and hydrometric conditions at typical spawning reaches and all but three are located in close proximity to established hydrometric stations. Staff gauges were installed at the three stations (F2, F6 and F7 in Figure 3.2) which were affected directly by tributary inflow between the station and the nearest hydrometric gauge. In addition to miscellaneous discharge measurements, cross-sectional surveys were conducted at each spawning station to determine areas, depths, widths and wetted perimeters for salmon reproduction requirements (Section 7.3).

Table 3.3

HISTORIC HYDROMETRIC DATA

Adjustment to Long-Term Mean Annual Flow (cfs)

Hydrometric Station		Period of Record	Mean April-September Flow				Long Term Mean Annual Flow	
Name	Number		Station Short Term Mean	South Thompson R. Short Term Mean	Station Adjusted Mean (1911-73)	South Thompson R. Seasonal to Annual Ratio	1911-73	1960-69
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Salmon R. above Salmon Lake	8LE075	1966-73	42.6	16,680	39.8	1.526	26.1	27.5
Salmon R. near Douglas Lake	8LE063	1952	46.2	16,440	48.9	1.681	26.1	27.5
Salmon R. above Aldelphi Creek	8LE019	1911-12 1918-21 1946 1965 1967-68 1970-73	88.4	16,210	85.1	1.567	54.3	57.2
Salmon R. near Westwold	8LE059	1946*	113.9	18,510	96.0	1.633	58.8	62.0
Salmon R. at Falkland	8LE020	1912 1915-18 1921 1948-61 1966-73	150.8	16,570	142.0	1.572	90.3	95.2
Salmon R. near Falkland	8LE064	1951-53	175.6	15,320	178.8	1.583	113.0	119.1
Salmon R. at Glenemma	8LE065	1951-53 1959-60	179.6	16,290	172.0	1.527	112.6	118.7
Salmon R. near Salmon Arm	8LE021	1912 1963-66 1969-73	240.9	16,140	232.9	1.537	151.5	159.7
Pringle Cr. near Westwold	8LE006	1912-14 1917 1919 1921-22 1926 1945-53	9.1	15,500	9.2	1.640	5.6	5.9
Ingram Cr. near Mouth	8LE008	1911-13 1915-17 1920-21	15.9	16,630	14.9	1.795	8.3	8.7
Bolean Cr. at Falkland	8LE001	1912-21 1951 1962-64	59.3	15,540	59.6	1.763	33.8	35.6
Fowler Cr. near ~~Falkland~~ Glenemma	8LE067	1956-60 1962 1964	5.0	16,340	4.8	1.505	3.2	3.4
Spa Cr. above Cowpersmith Div.	8LE042	1927 1931	5.1	14,800	5.4	1.459	3.7	3.9
Silver Cr. near Salmon Arm	8LE043	1924-28 1931 1945-48	11.8	15,560	11.8	1.557	7.6	8.0
Wilcox Cr. near Salmon Arm	8LE045	1931	3.8	13,860	4.2	1.562	2.7	2.8
Wallensteen Cr. nr. Salmon Arm	8LE046	1930-31	4.4	12,470	5.6	1.586	3.5	3.7
Gordon Cr. near Salmon Arm	8LE044	1931 1963 1966-73	15.9	16,050	15.4	1.528	10.1	10.6
Palmer Cr. near Salmon Arm	8LE072	1963 1968-73	11.6	16,210	11.1	1.523	7.3	7.7

*Seasonal period based on May to September

(4) Based on Reference (1)

(6) = $\frac{(4) \times 15{,}600}{(5)}$, mean April-September (1911-73) flow for South Thompson River is 15,600 cfs.

(8) = $\frac{(6)}{(7)}$

(9) = (8) X 1.054, South Thompson River mean annual flow for 1960-69 period is 5.4% of 1911-73 period.

Table 3.4 ACTIVE HYDROMETRIC STATIONS

Plot Number	Hydrometric Station Name	Hydrometric Station Number	Type of Record*	Type of Gauge*	Start of Record
	Water Survey of Canada Stations:				
1	Salmon River above Salmon Lake	8LE075	C	R	1966
11	Salmon River at Falkland	8LE020	C	R	1966
22	Salmon River above Kernaghan Cr.	8LE088	C	M	1973
28	Palmer Creek near Salmon Arm	8LE072	C	M	1968
29	Salmon River near Salmon Arm	8LE021	C	R	1973
	Monte Lake near Monte Lake	8LE068	S	M	1957
	B.C. Water Resources Service Stations:				
3	Weyman Creek near the Mouth	8LE095	S	M	1974
4	Salmon River above Adelphi Creek	8LE019	C	M	1974
7	Ingram Creek near the Mouth	8LE008	C	M	1975
9	Bolean Creek near the Mouth	8LE094	C	M	1974
12	Salmon River near Falkland	8LE064	C	M	1974
13	Salmon River at Glenemma	8LEB08	C	M	1974
14	Salmon River near Glenemma	8LE097	C	M	1974
15	Salmon River above Fowler Creek	8LE089	C	M	1974
16	Fowler Creek at 2100 ft. Contour	8LE096	C	M	1974
18	Salmon River above Silver Creek	8LE098	C	M	1974
20	Salmon River below Silver Creek	8LE090	C	M	1974
23	Kernaghan Creek above Diversions	8LE091	C	R	1974
25	Gordon Creek above Diversions	8LE092	C	R	1974
27	Palmer Creek above Diversions	8LE093	C	R	1974

* C, continous operation

S, seasonal operation

M, manual gauge

R, recording gauge

Table 3.5 OBSERVED TRIBUTARY RUNOFF

Plot No.	Hydrometric Station		Area Above EZR*	1975 Water Year$^{\Delta}$		Aug., 1975		Sept., 1975		Oct., 1975	
	Name	Number	(sq.mi.)	(cfs)	(in.)	(cfs)	(in.)	(cfs)	(in.)	(cfs)	(in.)
1	Salmon R. ab. Salmon Lake	8LE075	55.0	27.0	6.7	5.8	1.4	5.0	1.2	4.9	1.2
3	Weyman Cr. nr. the Mouth	8LE095	37.3	18.9	6.9	1.1	0.4	1.1	0.4	-	-
9	Bolean Cr. nr. the Mouth	8LE094	77.0†	40.1	7.1	11.4	2.0	13.6	2.4	12.3	2.2
16	Fowler Cr. at 2100 ft. contour	8LE096	6.1	3.9	8.7	2.0	4.5	1.7	3.8	2.0	4.5
23	Kernaghan Cr. ab. Diversions	8LE091	3.6	4.4	16.6	2.0	7.5	1.4	5.3	2.2	8.3
25	Gordon Cr. ab. Diversions	8LE092	7.5	12.3	22.3	2.6	4.7	2.2	4.0	3.3	6.0
27	Palmer Cr. ab. Diversions	8LE093	6.2	8.6	18.8	4.2	9.2	2.2	4.8	1.6	3.5

*EZR, Elevation of zero runoff: for 1975 Water Year runoff, use 3000 ft. for the dry zone (stations 1,3 and 9) and 1500 ft. for the wet zone (stations 16,23,25 and 27).

†EZR for Station 9 was adjusted using half of the drainage area for each of the two zones, the approximate split caused by the zone boundary. The area is adjusted from Table B.2 as 77.0 sq.mi., the average of 69.6 and 84.3 sq.mi. Observed runoff for this station was adjusted for upstream licensed irrigation withdrawals: 39.2 measured + 0.9 irrigation = 40.1 observed, 8.8 + 2.6 = 11.4 and 12.5 + 1.1 = 13.6.

$^{\Delta}$1975 Water Year is from November, 1974 to October, 1975.

Note the conversion of cfs to in.: (cfs) x 13.584 $\left(\frac{\text{sq.mi.in.}}{\text{cfs-yr.}}\right)$ ÷ area (sq.mi.) above zero runoff elevation.

3.6 Groundwater Network

Data are available from four observation groundwater wells in the Salmon River basin. To conduct the groundwater-return flow portion of the study (Section 6.3) the Groundwater Section of the Water Investigations Branch in 1974 drilled and equipped with water level recorders a series of nine observation wells on a farm field adjacent to the Salmon River between stations 8LE097 and 8LE089 (Figure 3.1). A tenth production well was drilled for a 25-hour pumping test to evaluate transmissivity and permeability of the aquifer. In addition to monitoring daily water table fluctuations, observation wells were used for pump tests (2 hours) and monthly water quality sampling. In the spring of 1975 two pipe flow meters were installed on the two diversions from the Salmon River which irrigated the test site. A standard daily rain gauge was established on the site to monitor rainfall input for water balance analysis.

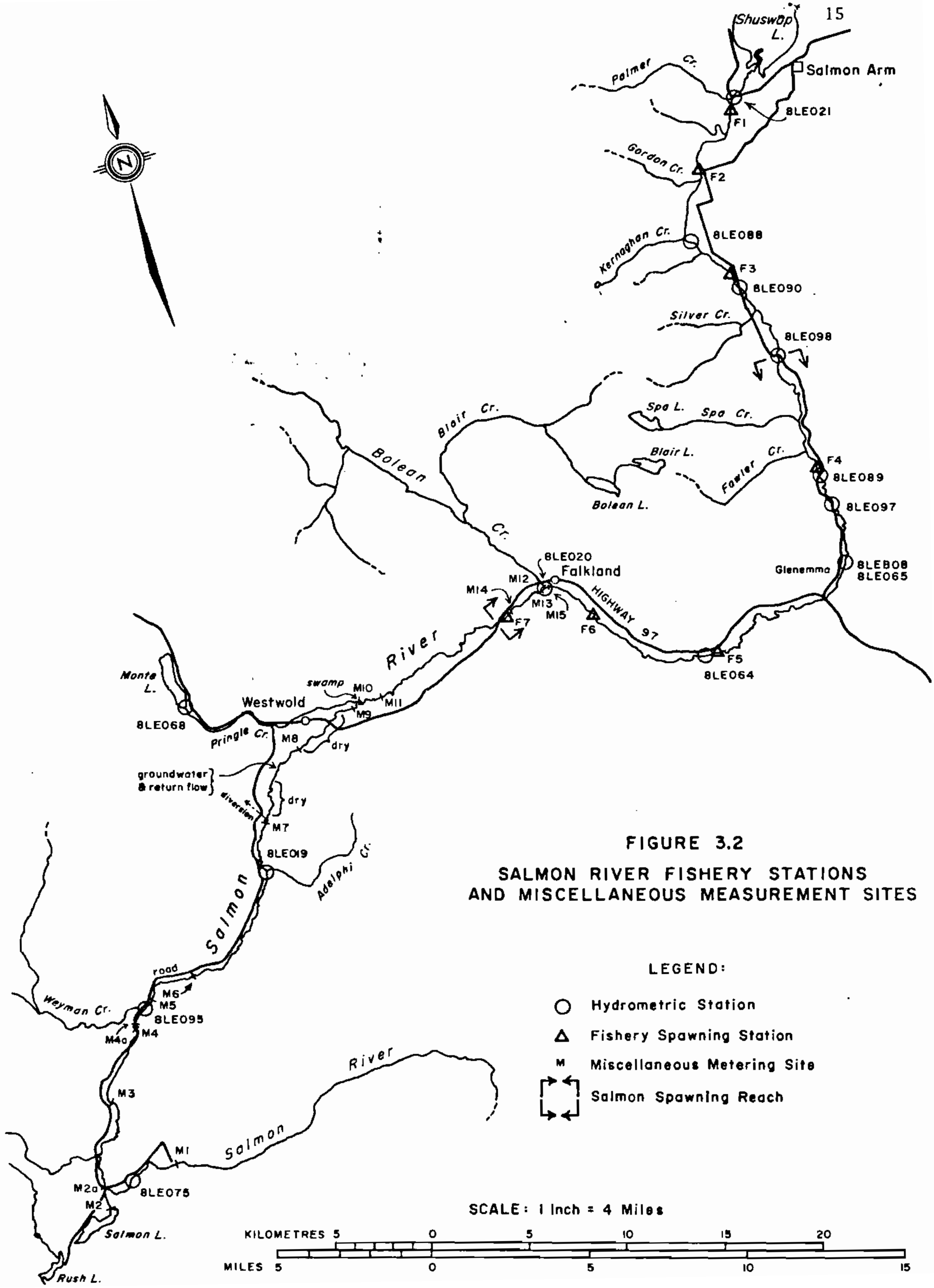

FIGURE 3.2
SALMON RIVER FISHERY STATIONS AND MISCELLANEOUS MEASUREMENT SITES

4. TRIBUTARY HYDROLOGY

4.1 Hydrologic Zones

The analysis of regional precipitation and runoff (Section 4.4) data revealed the presence of two hydrologic zones covering the Salmon River basin. Figure 3.1 shows the extent of the zones whose oval-shaped outer boundary ranges in distance approximately four to twenty miles from the Salmon River drainage boundary. The basin is divided approximately in half with a dry zone west and a wet zone east of Falkland.

Precipitation data was plotted against elevation in two seasonal components, summer and winter, in order to incorporate the higher elevation snow course data. The winter period was defined from November to March based on an analysis of mean monthly temperature distribution throughout the elevation range of the Salmon River basin. Accumulated winter season precipitation at meteorologic stations and April 1st snow water equivalent at snow courses were combined and plotted against station elevation as shown in Figures B.1 through B.9 in Appendix B. Trial plots showed that semi-log graph paper produced the best linear relationships. The winter plots distinctly revealed the two hydrologic zones. Figures B.1, B.5 and B.8 show that significant melt may occur at the lower elevation snow course 85; this was substantiated by examination of the snow survey records which showed a loss in water equivalent from March 1st to April 1st in many years. Other sources of error may be ablation due to wind effects on open exposure and lower precipitation influence of the neighbouring Nicola River region. Monte Lake (precipitation station) plots slightly above the dry zone curve suggesting a narrow transition zone rather than a sharp division between the two regions; however there is insufficient data to define the transition zone. The remaining stations display a reasonable scatter for this type of relationship reflecting different station exposures and localized micro-climatologic variation.

To complete the annual precipitation-elevation relationship, accumuated summer season precipitation for the April to October period was plotted on semi-log graph paper. There are no high elevation summer precipitation observations to define the higher portion of the relationship. However, the curves were extrapolated by a comparison with high elevation meteorologic stations (Mount Lolo Kamloops and McCulloch) some distance from the watershed. These points are approximate and serve only as a guide. Again, the summer plots revealed the two hydrologic zones defined by the winter plots.

Mean monthly and annual temperatures plotted against station elevation produced straight line relationships (on semi-log graph paper) with little scatter of data points. As for precipitation, high elevation meteorologic stations outside the zone boundaries were used to extend the higher portion of the curve. The annual and example monthly plots, shown in Figures B.3, B.7 and B.10 of Appendix B, indicated a similar temperature pattern throughout the Salmon River basin. The precipitation plots exhibited a wider scatter than the temperature plots due to the greater dependence of precipitation on localized atmospheric and physiographic conditions.

The temperature and precipitation plots were used to provide data input for the water balance model described in the next section. These data were distributed on a monthly basis using observed temperature and precipitation monthly to annual percentage ratios for high and low elevation ranges in both hydrologic zones.

4.2 Water Balance Runoff Model

The water balance runoff model of Reference 8 was used to estimate hydrologic components for the purpose of analyzing the Salmon River hydrologic regime and defining the elevation of zero runoff (Section 4.3). The model employs mean monthly temperature, mean monthly precipitation and elevation data to calculate mean monthly hydrologic components, including temperature, precipitation, evapotranspiration and runoff for 500-foot elevation bands of each hydrologic zone. The mean temperature and precipitation-elevation curves and monthly percentage distributions provided elevation band input data for the water balance computer program. Calculations were performed on a mean monthly basis for elevation bands from 1000 to 8000 feet for each of the hydrologic zones. The computer output runoff results have been plotted in Figure B.11 of Appendix B.

4.3 Elevation of Zero Runoff

The elevation of zero runoff (EZR) in a watershed is that elevation at which potential evapotranspiration equals precipitation and results in insignificant contribution to surface runoff on an annual basis. In short time periods when rainfall or snowmelt rates exceed soil infiltration capacity, surface runoff would occur. Reference 7 demonstrates that no surface (mean annual) runoff occurs approximately below 4000 feet in the Okanagan valley and Reference 10 stipulates 4000 feet for the dry zone and 3500 feet for the wet zone of the Similkameen basin. The water balance runoff model results plotted in Figure B.11 show that in the Salmon basin in average years EZR in the wet zone is approximately 2000 feet and in the dry zone, 3500 feet. EZR would tend to remain constant in average years but would vary in extreme years, descending in wet years and ascending in dry years.

4.4 Runoff-Elevation Relationships

Runoff records were regionalized by graphical analysis of runoff versus elevation. For each gauged watershed, the median elevation of the runoff producing region (the area above EZR) was determined and plotted on log-log graph paper against 1960-1969 unit runoff from the contributing portion of the watershed (Figure B.4). The computed elevation-band runoff from the water balance model was superimposed on this plot and is compared with the observed curves in Table 4.1. In the 4000 to 5000 foot median elevation range of the dry zone the water balance curve represents closely the observed runoff-elevation relationship and the observed curve was therefore considered to be coincident with the water balance curve. The maximum error is +18% for the smallest observed flow of 8.7 cfs (6.4 in.) for Ingram Creek (8LE008). The errors for the dry zone are relatively small and all are positive which is reasonable when underflow is considered, e.g., Salmon River above Adelphi and near Westwold. The drainage area of tributary 10, Bolean Creek (8LE001) is covered in approximately equal portions by both zones as shown in Figure 3.1 and thus plots approximately equidistant between the two observed curves. However, for the wet zone the observed curve plots

Table 4.1 COMPARISON OF OBSERVED AND ESTIMATED WATER BALANCE RUNOFF

(1960-1969 Mean Annual Runoff)

Plot No.	Hydrometric Station		Observed Runoff			Estimated Runoff		% Erro
	Name	Number	Measured Flow (cfs)	Measured Flow plus Irrigation Withdrawals (cfs)	(in.)	(cfs)	(in.)	
	Dry Hydrologic Zone (above 3500 ft. elevation)							
1	Salmon R. ab. Salmon Lk.	8LE075	27.5	27.5	7.5	27.8	7.6	+1
2	Salmon R. nr. Douglas Lk.	8LE063	27.5	28.4	5.2	32.7	6.0	+15
4	Salmon R. ab. Adelphi Cr.	8LE019	57.2	59.4	5.1	67.2	5.8	+14
5	Salmon R. nr. Westwold	8LE059	62.0	67.2	5.5	70.9	5.8	+5
8	Ingram Cr. nr. Mouth	8LE008	8.7	8.7	5.4	10.3	6.4	+18
10	Bolean Cr. at Falkland	8LE001	35.6	36.6	7.1*	37.2	7.2*	-
11	Salmon R. at Falkland	8LE020	95.2	111.2	5.9	114.5	6.1	+3
	Wet Hydrologic Zone (above 2000 ft. elevation)							
16	Fowler Cr. at 2100 ft. contour	8LE096	3.4	3.4	7.6	4.2	9.4	+24
17	Spa Cr. ab. Cowersmith Div.	8LE042	3.9	3.9	12.9	4.8	16.0	+24
19	Silver Cr. nr. Salmon Arm	8LE043	8.0	8.3	13.0	8.6	13.5	+4
21	Wilcox Cr. nr. Salmon Arm	8LE045	2.8	2.8	19.0	1.8	12.1	-36
24	Wallensteen Cr. nr. Salmon Arm	8LE046	3.7	3.7	12.9	5.0	17.3	+34
26	Gordon Cr. nr. Salmon Arm	8LE044	10.6	10.8	19.8	8.5	15.6	-21
28	Palmer Cr. nr. Salmon Arm	8LE072	7.7	8.0	17.0	7.5	16.0	-6
29A	29-11		64.5	77.5	8.8	59.6	6.8	-23
29	Salmon R. nr. Salmon Arm	8LE021	159.7	188.7		174.1		Σ 0

*Runoff from tributary 10 was estimated assuming half of the area from each of the two hydrologic zones, the approximate split defined by the zone boundary (Figure 3.1).

Note the conversion of cfs to in.: $(\text{in.}) = (\text{cfs}) \times 13.584 \left(\frac{\text{sq.mi.in.}}{\text{cfs-yr.}}\right) \div \text{area (sq.mi.)}$ above zero runoff elevation.

lower than the water balance curve. The observed curve was positioned to produce a net accumulated zero error for the dry zone, while at the same time maintaining the zero runoff elevation, (Table 4.1) following the procedure of Reference 10. Percent errors vary between -36% and +34% which are not unreasonable considering that they represent estimates for very small annual flows of 2.8 and 3.7 cfs and that groundwater underflow and interflow is highly likely in the permeable valley floor. The water balance runoff model over-estimates all observed runoff in the wet zone for the 1960-1969 period which may be due to inadequate precipitation input data relationships, especially in the upper elevations. The dry zone also infers this but to a smaller degree by the gauged tributary basins which experience minor (or no) underflow and no upstream diversions such as in stations one and eight. Model errors are also discussed for the 1975 flows in the following section.

4.5 Watershed Yield

The water balance runoff model was also used to calculate annual runoff for individual years of 1974 and 1975 based on a water year period from November to October. The resultant water balance runoff-elevation curves are plotted in Figure B.11 along with the mean 1960-1969 curve for comparison. The observed curves and flows are plotted in Figure B.12 using observed data of Table 3.5 and basin area-elevation characteristics of Table B.2. The observed curves were drawn with slopes similar to those of the water balance runoff curves (Figure B.11) in the elevation range of meteorologic data (Figures B.8 to B.10) and positioned to produce a net accumulated zero error as with the 1960-1969 water balance runoff plots. Table 4.2 lists the 1975 water year runoff estimates with errors for the tributaries whose gauges are not affected significantly by underflow or diversions. Tributary 9, Bolean Creek, observed flow was adjusted for minor diversion as per Table 3.5 but its error is not defined since it is positioned to reflect equal area contribution between the two zones as per Section 4.4. The observed curves (Figure B.12) were used to estimate runoff for mainstem gauging points by assigning a unit runoff from the observed curves

Table 4.2 EXPECTED ANNUAL RUNOFF* AT SALMON RIVER STATIONS BY THE WATER BALANCE METHOD

1975 Water Year

(November to October)

Plot No.	Hydrometric Station Name	Number	Estimated Runoff (cfs)	Estimated Runoff (in.)	Observed Runoff† (cfs)	Observed Runoff† (in.)	% Erro
	Tributary Stations:						
1	Salmon River above Salmon Lake	8LE075	27.1	6.7	27.0	6.7	0
3	Weyman Creek near the Mouth	8LE095	18.9	6.9	18.9	6.9	0
9	Bolean Creek near the Mouth	8LE094	40.1	7.1	40.1	7.1	-
16	Fowler Cr. at 2100 ft. contour	8LE096	5.0	11.2	3.9	8.7	+29
23	Kernaghan Cr. above Diversions	8LE091	4.9	18.5	4.4	16.6	+11
25	Gordon Creek above Diversions	8LE092	8.9	16.1	12.3	22.3	-28
27	Palmer Creek above Diversions	8LE093	7.5	16.5	8.6	18.8	-12
							Σ 0
	Mainstem Stations:						
1	Salmon River above Salmon Lake	8LE075	27.1				
4	Salmon River above Adelphi Cr.	8LE019	72.1				
11	Salmon River at Falkland	8LE020	121.5				
12	Salmon River near Falkland	8LE064	133.3				
13	Salmon River at Glenemma	8LEB08	144.1				
14	Salmon River near Glenemma	8LE097	146.7				
15	Salmon River above Fowler Cr.	8LE089	151.5				
18	Salmon River above Silver Cr.	8LE098	168.6				
20	Salmon River below Silver Cr.	8LE090	178.8				
22	Salmon River ab. Kernaghan Cr.	8LE088	185.6				
29	Salmon River near Salmon Arm	8LE021	210.9				

*Expected mainstem runoff is the total runoff contributed by the tributary basins and would occur if there were no water withdrawals or groundwater losses and interactions.

†Observed runoff (taken from Table 3.5) has been adjusted for licensed irrigation withdrawals.

corresponding to the median elevation of the runoff contributing area. Below Falkland mainstem estimates were done in two steps, once for each zone contribution, and then totaled for the overall basin up to the gauged point. Detailed calculations are shown in Table B.2 (Appendix B) and mainstem runoff estimates are summarized in Table 4.2. The observed curve errors appear reasonable for the tributaries but cannot be determined for mainstem stations since measured runoff is the residual flow after groundwater losses. Hence the runoff estimates for mainstem stations represent expected runoff which would occur before irrigation withdrawals and groundwater underflow.

The water balance curves for 1975 were useful for defining elevation of zero runoff and curve slopes but are significantly higher along the vertical axis than those of the observed curves of both zones. It should be emphasized that this application is for an individual year whereas the model was designed for a mean year when (groundwater and surface) storage carryover effects and other water balance component errors would be compensated for when estimating a mean year over a long period of time. This is especially true for small catchments located in areas where the data base is of low station density and poor time distribution in periods of record.

Accurate estimates of expected runoff are required to determine the magnitude of the groundwater flow component in the mainstem flow regime system (Section 9). Since mainstem estimates cannot be checked directly independent estimates are desirable for comparative purposes. An independent technique was used to estimate expected mainstem runoff using hydrometric data collected for the 1975 water year by seven tributary gauges as shown in Table 3.5. Table 4.3 displays the technique whereby the Salmon River is segmented into separate drainage units or reaches between mainstem gauging points. Each drainage reach is assigned an observed unit runoff as defined by the closest gauged tributary (or averages if more than one tributary reflects conditions within reach) shown in the second column. Observed tributary unit runoff was derived by converting the observed flow at each gauge to unit runoff for the area above EZR. Estimates for each drainage reach were then accumulated along the Salmon River channel to produce expected runoff estimates at each mainstem gauging point. A comparison of the results of the two techniques (Tables 4.2 and 4.3) shows that the expected runoff estimates are the same at the upstream station (8LE075) but gradually diverge to a difference of 85 cfs at the downstream station (8LE021). Table 4.4 lists observed flows (measured runoff plus licensed irrigation withdrawals) and a comparison indicates that the water balance method underestimates whereas

Table 4.3 EXPECTED ANNUAL RUNOFF AT SALMON RIVER STATIONS BY THE MEASURED TRIBUTARY RUNOFF METHOD

1975 Water Year
(November to October)

Plot	Hydrometric Station		Area Above EZR*	Estimated Runoff		
Number	Name	Number	(sq.mi.)	(in.)	Δ(cfs)	Σ(cfs)
1	Salmon R. ab. Salmon Lk.	8LE075	55.0	6.7	27.1	27.1
4-1	(average 1 & 3)		145.0	6.8	72.6	
4	Salmon R. ab. Adelphi Cr.	8LE019	200.0			99.7
11-4	(average 9 & (1 & 3))		130.0	7.0	67.0	
11	Salmon R. at Falkland	8LE020	330.0			166.7
12-11	(16)		29.6	8.7	19.0	
12	Salmon R. nr. Falkland	8LE064	359.6			185.7
13-12	(16)		19.2	8.7	12.3	
13	Salmon R. at Glenemma	8LEB08	378.8			198.0
14-13	(16)		9.3	8.7	6.0	
14	Salmon R. nr. Glenemma	8LE097	388.1			204.0
15-14	(16)		2.7	8.7	1.7	
15	Salmon R. ab. Fowler Cr.	8LE089	390.8			205.7
18-15	(16)		29.3	8.7	18.8	
18	Salmon R. ab. Silver Cr.	8LE098	420.1			224.5
20-18	(average 16 & 23)		18.0	12.6	16.7	
20	Salmon R. bl. Silver Cr.	8LE090	438.1			241.2
22-20	(23)		8.0	16.6	9.8	
22	Salmon R. ab. Kernaghan	8LE088	446.1			251.0
29-22	(average 23, 25 & 27)		32.0	19.2	45.2	
29	Salmon R. nr. Salmon Arm	8LE021	478.1			296.2

*EZR, elevation of zero runoff

the tributary runoff method overestimates what would reasonably be expected runoff. Hence the two Tables 4.2 and 4.3 were averaged to produce the expected annual runoff shown in Table 4.4.

Monthly flow estimates at mainstem stations were derived for the low flow months of 1975 by applying ratios of observed monthly to annual flows (adjusted for licensed irrigation withdrawals) to estimated annual runoff. Table 4.4 lists observed monthly runoff and irrigation components (Section 9.3), monthly to annual ratios and estimated monthly and annual runoff. The mainstem monthly to annual ratios are consistent except for the two upstream stations. Station 8LE075 is a small headwater tributary whose drainage area is narrow, very steep and rocky and therefore characterized by rapid freshet runoff and low baseflow. Station 8LE019 is located on a permeable valley floor just upstream of the Westwold aquifer (Section 6.1) and may be influenced by significant groundwater flow in the low flow months. Below Westwold the monthly to annual ratios are consistent throughout the Salmon River, showing a stable pattern in variation of flow with channel distance.

Table 4.4

EXPECTED MONTHLY RUNOFF AT SALMON RIVER STATIONS

1975 Water Year (November to October)

Plot No.	Salmon River Hydrometric Station	Measured Runoff (cfs)				Measured Runoff plus Irrigation Withdrawals (cfs)				Ratio of Monthly to Annual Measured plus Irrigation Flows			Expected Runoff* (cfs)			
		Annual	Aug.	Sept.	Oct.	Annual	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.	Annual	Aug.	Sept.	Oct.
1	ab. Salmon Lk. (8LE075)	27.0	5.8	5.0	4.9	27.0	5.8	5.0	4.9	0.215	0.185	0.181	27.1	5.8	5.0	4.9
4	ab. Adelphi Cr. (8LE019)	52.9	11.0	5.9	4.3	55.1	17.6	8.6	4.3	0.319	0.156	0.078	85.9	27.4	13.4	6.7
11	at Falkland (8LE020)	104.6	46.6	43.0	43.6	120.6	90.8	61.3	43.6	0.753	0.508	0.362	144.1	108.5	73.2	52.2
12	nr. Falkland (8LE064)	100.4	42.9	37.4	37.9	118.6	93.5	58.3	37.8	0.788	0.492	0.319	159.5	125.7	78.5	50.9
13	at Glenemma (8LEB08)	128.1	55.4	49.0	52.8	149.2	114.4	73.4	52.8	0.767	0.492	0.354	171.0	131.2	84.1	60.5
14	nr. Glenemma (8LE097)	115.0	46.1	47.2	46.7	136.8	107.1	72.4	46.7	0.783	0.529	0.341	175.4	137.3	92.8	59.8
15	ab. Fowler Cr. (8LE089)	112.2	43.1	40.7	39.1	134.1	104.5	66.1	39.1	0.779	0.493	0.292	178.6	139.1	88.0	52.2
18	ab. Silver Cr. (8LE098)	150.6	52.8	50.6	48.9	173.9	118.4	77.7	48.9	0.681	0.447	0.281	196.6	133.9	87.9	55.2
20	bl. Silver Cr. (8LE090)	152.2	59.2	57.5	59.0	176.5	127.7	85.8	59.0	0.724	0.486	0.334	210.0	152.0	102.1	70.1
22	ab. Kernaghan Cr. (8LE088)	145.3	58.6	53.8	53.4	170.5	129.8	83.2	53.4	0.761	0.488	0.313	218.3	166.1	106.5	68.3
29	nr. Salmon Arm (8LE021)	199.0	83.7	73.2	73.1	228.0	166.2	107.3	73.1	0.729	0.471	0.321	253.6	184.9	119.4	81.4

*Estimates of expected annual runoff for the 1975 water year are averages of estimates by the water balance method (Table 4.2) and the measured tributary runoff method (Table 4.3). Monthly estimates are derived from the annual estimates and ratios of monthly to annual measured plus irrigation flows to reflect an actual monthly distribution at mainstem gauges.

5. MAINSTEM CHANNEL REGIME

5.1 Channel Regime Description

The Salmon River flows for 92 miles from its source on Bouleau Mountain through a number of geologic and soil formations to Shuswap Lake. Above Salmon Lake, the river at base flow conditions behaves as a steep sloped tributary with flow increasing with contributing drainage. (Figure 5.1 shows the mainstem channel profile and Figure 5.2, the drainage area profile.) Bypassing Salmon Lake, the river flattens out in a narrow valley bottom of unconsolidated deposits. This formation affects the flow by groundwater storage in addition to the storage effects from tributary Rush and Salmon Lakes. Groundwater discharge appears in the valley bottom downstream of Salmon Lake. From the Salmon Lake valley the river again drops steeply (800 feet in 10 miles) into the highly permeable unconsolidated deposits that characterize the start of the Salmon River valley above Westwold. Near the mouth of Adelphi Creek, channel seepage losses become significant (10 to 15 cfs) and the river flow decreases. At 1.4 miles below Adelphi Creek, after an irrigation diversion, (3.5 cfs in Appendix B) it disappears completely during base flow. Two miles downstream, groundwater outflow and irrigation return flow establish intermittant river flow for approximately 1.5 miles. The channel then remains dry until the mouth of Pringle Creek where an extensive groundwater aquifer surfaces to establish (flow measured at 20 cfs in Appendix B) and sustain a flow for the remaining length of the river to Shuswap Lake. The variability of the mainstem base flow downstream from Falkland is governed more by groundwater interflow due to geologic and stream bed formations than by tributary inflow and irrigation withdrawals.

At other flow conditions, the Salmon River has similar variation to the base flow regime but with increased magnitude. In the upper part of the Westwold valley in an average flow year the river starts to flow when initial infiltration losses are met at approximately 40 cfs as suggested in Reference 13. There is some variation of infiltration loss from the river being greater during high stages than during low flow. During high flows stream beds are porous and extra channels are flowing but during low flow channel beds are

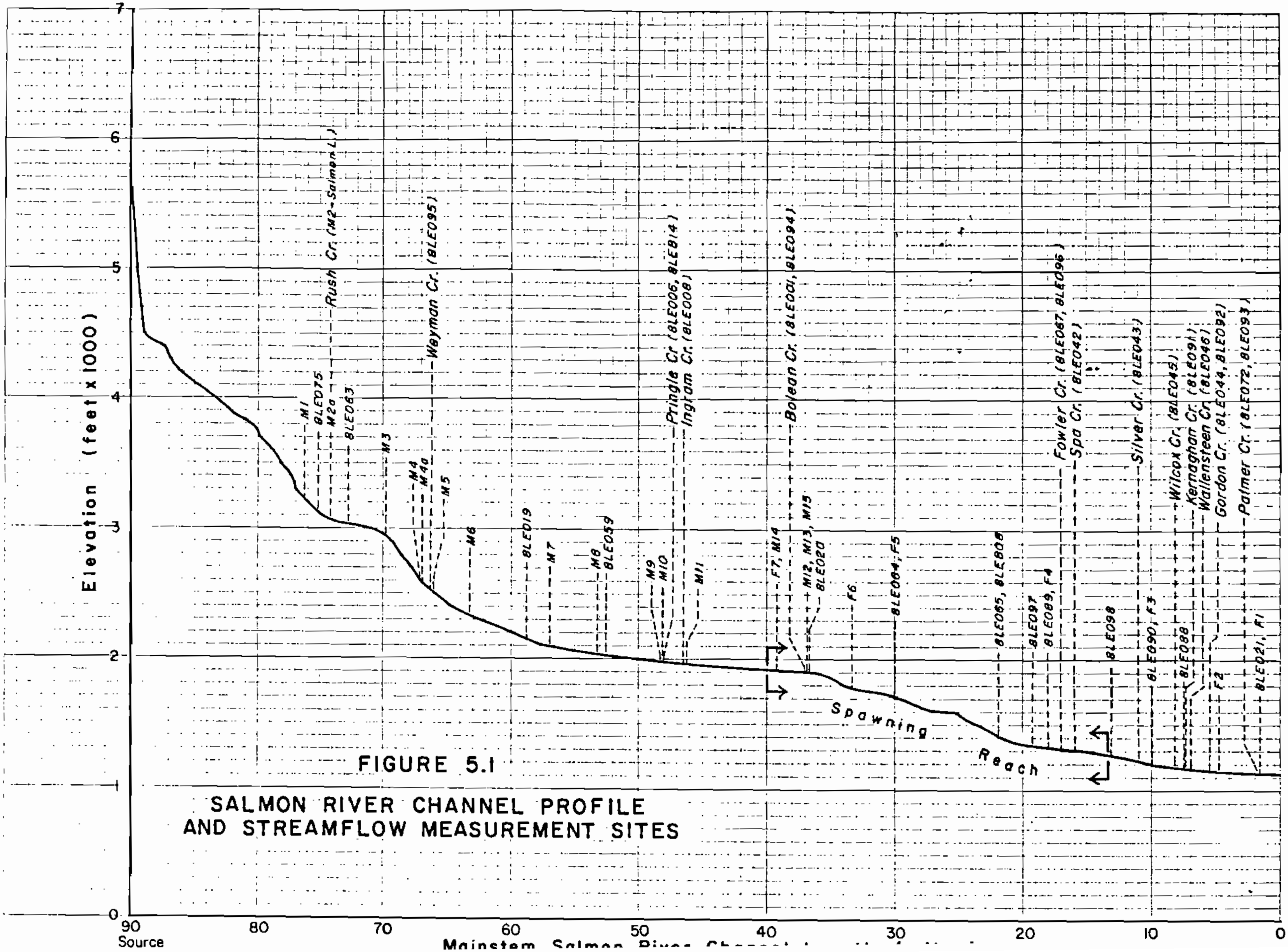

FIGURE 5.1

SALMON RIVER CHANNEL PROFILE
AND STREAMFLOW MEASUREMENT SITES

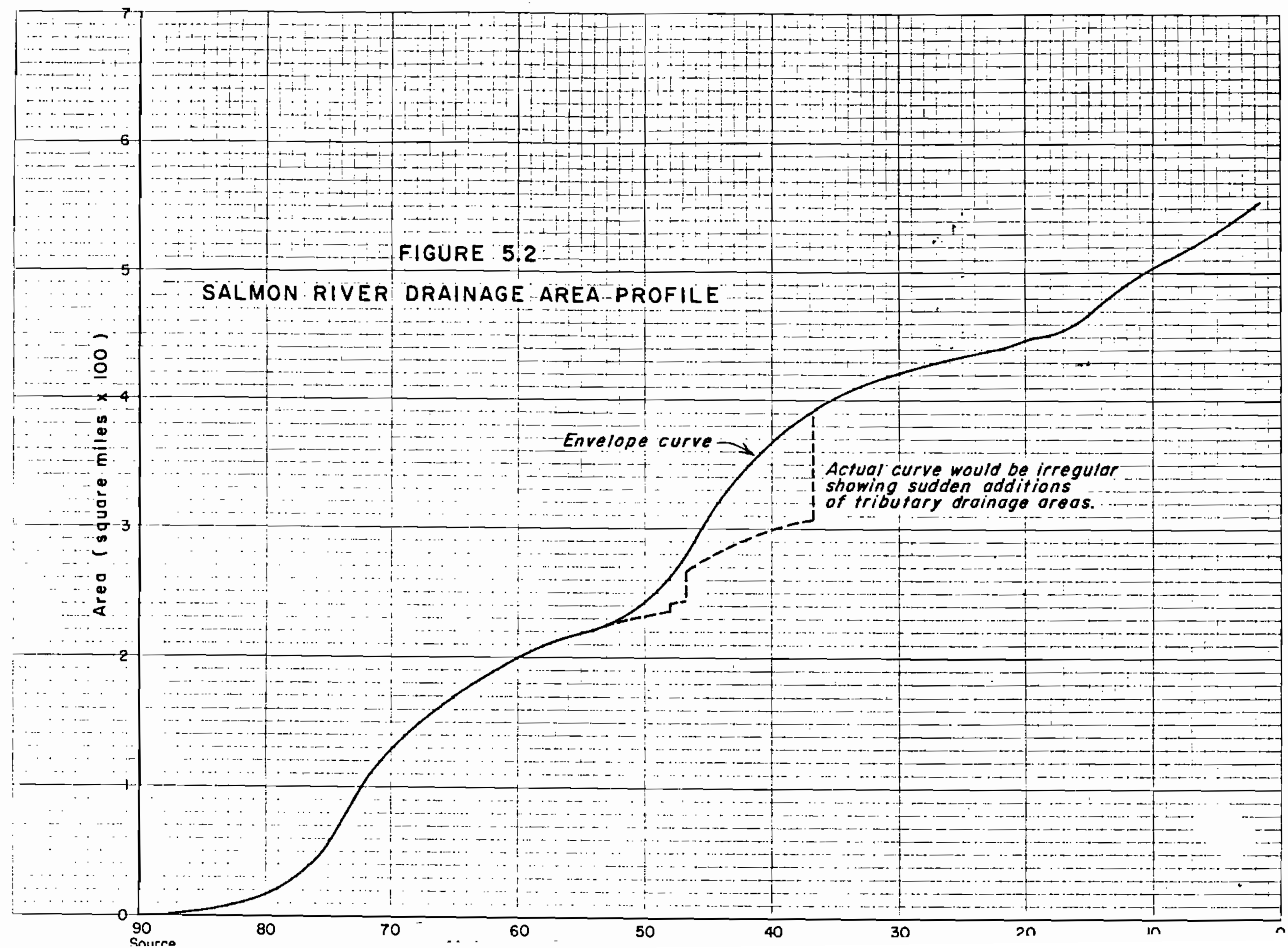

FIGURE 5.2

SALMON RIVER DRAINAGE AREA PROFILE

silted and lower the infiltration rate. (Figures 9.3 to 9.6 show a decrease in total groundwater component with decrease in flow.) At Westwold bridge, below irrigation diversions, channel flow appears about mid-April and ceases in early July, for a period of about 2½ to 3 months each year. In a very high flow year with heavy summer precipitation the river would flow for the full year satisfying losses in the whole channel. The effect of local surficial and bedrock geology on water movement in the Salmon River basin is discussed in Section 6.

5.2 Channel Regime Survey

A mainstem channel survey was carried out to measure the base flow regime and to identify water resource problems. The critical time for conflicting water use, siltation and channel water loss problems is during the low flow period from August to October of each year. A preliminary inspection of the Salmon River channel from the vicinity of Salmon Lake to the mouth at Salmon Arm was made to select miscellaneous measurement points for defining channel flow variability and to identify fishery spawning reaches (Section 3.5). These sites are shown on the regional map of Figure 3.2 and the channel profile curve of Figure 5.1. Streamflow metering was conducted at regular, miscellaneous and fishery hydrometric stations during base flow in mid-September 1974, but the time span of 8 days was too long for measuring a static flow regime. The streamflow metering was repeated in late September, 1975 over a period of 3 days. The measured discharges and associated data are listed in Appendix B and were used as input to the analyses of Sections 6 and 9.

The channel survey did not reveal any specific water withdrawals that appeared to have direct or significant conflict with spawning requirements. Typical channel flow restrictions, due to siltation, to fish access were observed at two sites, near the mouth and upstream from Silver Creek. Measures for channel improvements are discussed in Section 11.2. At Westwold, total underflow during August and September blocks any upstream fish migration.

6. GROUNDWATER REGIME

6.1 Regional Geology and Groundwater Regime

The Salmon River lies in an almost continuous belt of unconsolidated deposits which overly volcanic and metamorphic rock. Groundwater associated with bedrock occurs mainly within volcanic basaltic lava in the upper half and in metamorphic argillites and schists in the lower half of the Salmon River basin. Both types of bedrock have low porosity and permeability. There is considerable faulting in the region, some of which cuts across the basin, especially pronounced between Falkland and Glenemma. Occurrence of groundwater within the bedrock is associated with such rock fractures but faulting may not cause significant groundwater movement into and out of the Salmon River basin. Well yield from bedrock is generally minimal and is estimated to be less than 5 U.S. gallons per minute per well.*

The surficial geology of the Salmon River valley consists of unconsolidated fill deposits described as till, clay, silt, sand and gravel and which range from low to high porosity and permeability. In the upper part of the valley from Salmon Lake which lies on pleistocene glacial deposits, the river drains through short reaches of argillite and schist surface rock zones and then longer reaches of basaltic lava to the mouth of Adelphi Creek. From here the river runs through a continuous belt of unconsolidated deposits except for a short reach of andesite lava outcrop above Falkland. Within the main valley and tributary fan areas, sand and gravel deposits commonly occur in depths from 50 to 100 feet. Below these depths silt and clay is often recorded on well logs to depths of about 300 feet. The most significant occurrence of groundwater in the basin is in the surficial deposits of the valley floor and mouths of tributary creeks. Well yields from these deposits are generally high, often between 500 and 1000 U.S. gallons per minute.

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*Geological formation descriptions are based on Geological Survey of Canada maps. Groundwater flow estimates were provided by E.G. Le Breton.

The main influence governing the direction of groundwater movement in the basin is topography. Terrace remnants and alluvial cones bordering the valley sides provide lateral groundwater movement (up to 2 cfs, depending on size of fan) in the upper part of the valley above Westwold and the middle portion above Glenemma. In these reaches, the Salmon River regime would appear to be independent of local fluctuations of the groundwater aquifers. The most important area of groundwater recharge in the river system is above Westwold where a large aquifer is fed primarily by the Salmon River whose channel is dry there throughout most of the year. This aquifer extends over the whole valley of Westwold and its discharge controls the downstream Salmon River flow to Falkland. This area and the O'Keefe valley adjoining Glenemma are both discussed in detail in the next section. Below Glenemma lateral groundwater flow is reduced by a longitudinal flow component that apparently increases with the valley bottom width which varies from 1500 feet near Glenemma to 1.7 miles at Shuwsap Lake. An example of the occurrence of three zones, a lateral, transitional and longitudinal groundwater movement zone is given in Section 6.3. Water table fluctuations of the latter zone would tend to relate more closely to river stages than the first zones, although all three exhibit general runoff trends during freshet and base flow. Hydraulically separate bodies of water occur in bordering terraces and alluvial fans, old river beds of permeable deposits and in zones adjacent to the main channel where a sediment barrier may have sealed the stream bed during receding flows. During base flow in the lower half of the basin, the Salmon River would generally tend to be effluent, infiltrating from the river to the adjoining water table. Groundwater flow here would be longitudinal adjacent to the river and lateral near the valley sides. Finally, longitudinal groundwater movement may be obstructed by a wall of less pervious deposits near the mouth of the Salmon River at Shuswap Lake, which would cause a high water table in the spring (Reference 13).

6.2 Groundwater Flow Component

An attempt was made by the Groundwater Section to relate streamflow to groundwater flow in two reaches of the Salmon River, at Westwold and downstream from Westwold to Falkland. The channel regime surveys of September

1974 and 1975 (Section 5) included miscellaneous measurements of 18 and 23 cfs at Site M11 downstream of the Pringle Creek-Salmon River confluence (Figure 3.2). These measurements represent the approximate outflow or yield of the Westwold aquifer. No detailed geologic study of the area was conducted but local ground water-level information was collected and used in conjunction with a long-term observation well hydrograph near Westwold. This information with an assumed aquifer porosity of 25% and an estimated aquifer area of four square miles was used to show that the existing ground-water storage is capable of sustaining a streamflow of approximately 20 cfs. This figure was used to calculate two possible permeability (K) values (using Darcy's equation, $Q = KIA$) for an assumed triangular area, between the start of channel flow and M11, and a stream bed area for the length of channel between the same points. This gave K values of 700 and 10,000 (U.S. gallons per day per square foot), respectively. The Darcy formula was applied to the Salmon River reach (M11 to M13) between Westwold and Falkland, where an observed 10 cfs increase in base flow gave a K of 2600 for the river bed area. A similar formula, $Q = TIL$, was applied in which Q = 20 cfs, T, the transmissivity, is (K)(aquifer thickness), K = 10,000, I, the river gradient (of the triangular area), is 0.0033 $ft/_{ft}$ and L, the width of the aquifer (between bedrock valley walls), is 7500 ft. The result was a 50 foot thick aquifer which compares favourably with local water well records. However, the formula applied to the Westwold-Falkland reach with contributing Q of 10 cfs and K of 2600 gave an aquifer of 325 feet which may be too thick for the Falkland region. It was concluded that contribution to groundwater storage and discharge occurs from fan deposits of tributaries and from stream bank storage during freshet flooding in low lying areas above Falkland. It was further concluded that if the 10 cfs increase in baseflow in this reach was totally from groundwater discharge that additional ground-water flow in this part of the valley is not likely.

For the Salmon River reach between Falkland and Glenemma, the channel survey described in Section 5 showed no increase in baseflow. Since there are no tributaries in this reach which contribute surface flow net ground-water discharge must be offset by irrigation withdrawals. This is supported by Figures 9.5 and 9.6 which show that expected net streamflow is almost coincident with measured streamflow at Falkland and Glenemma.

Two groundwater flow calculations were attempted for the Salmon River reaches below Falkland. A longitudinal component parallel to the river at the groundwater test site was calculated to be between two and three cfs using a T of 225,000 U.S. gal./day/ft. (from pump tests of Section 6.3) for a 500-foot strip on each side of the river and a T of 25,000 for a remainder 1.5 miles of valley width across the site. Another calculation was made for possible underflow from the Salmon to the Okanagan River basin. Surveys of water levels showed that the hydraulic gradient of the Salmon River from the adjacent O'Keefe Valley to Glenemma was the same as that from the Salmon River to the northern lake in the O'Keefe Valley. Groundwater underflow of up to 4 cfs was shown possible (Reference 3) but this is a tentative conclusion since only two wells were used and the depth of unconsolidated deposits is not known in this region.

Recommendations were made for a deep test well to be drilled in the Westwold area along with lines of observation wells and further pump tests of existing wells. A hydrometric station was also recommended for site M11 to facilitate a further surface-groundwater hydrology study.

6.3 Groundwater-Return Flow Measurement Site

The return flow investigation of the groundwater portion of this study conducted by the Groundwater Section was carried out on a test site adjacent to the Salmon River (see Section 3.6). The test site lies on a valley floor plain of glacial and recent terrace deposits, has an almost flat topographic gradient at an average elevation of 1370 feet and does not experience surface drainage. The soil formation comprises two to five feet of silt and clay on top of 10 feet of sand, gravel and pebbles. Below this level the remaining stratum varies from fine to medium sand to coarse sand and gravels and extends to an unknown depth of unconsolidated deposits.

The predominant groundwater movement at the test site as shown by the hydraulic gradient on plotted water level maps is from south to north parallel to the Salmon River channel at both high and low runoff stages (Figure 6.1). This is contrary to the topographic gradient which runs from west to east, towards the river. However, during local groundwater recharge

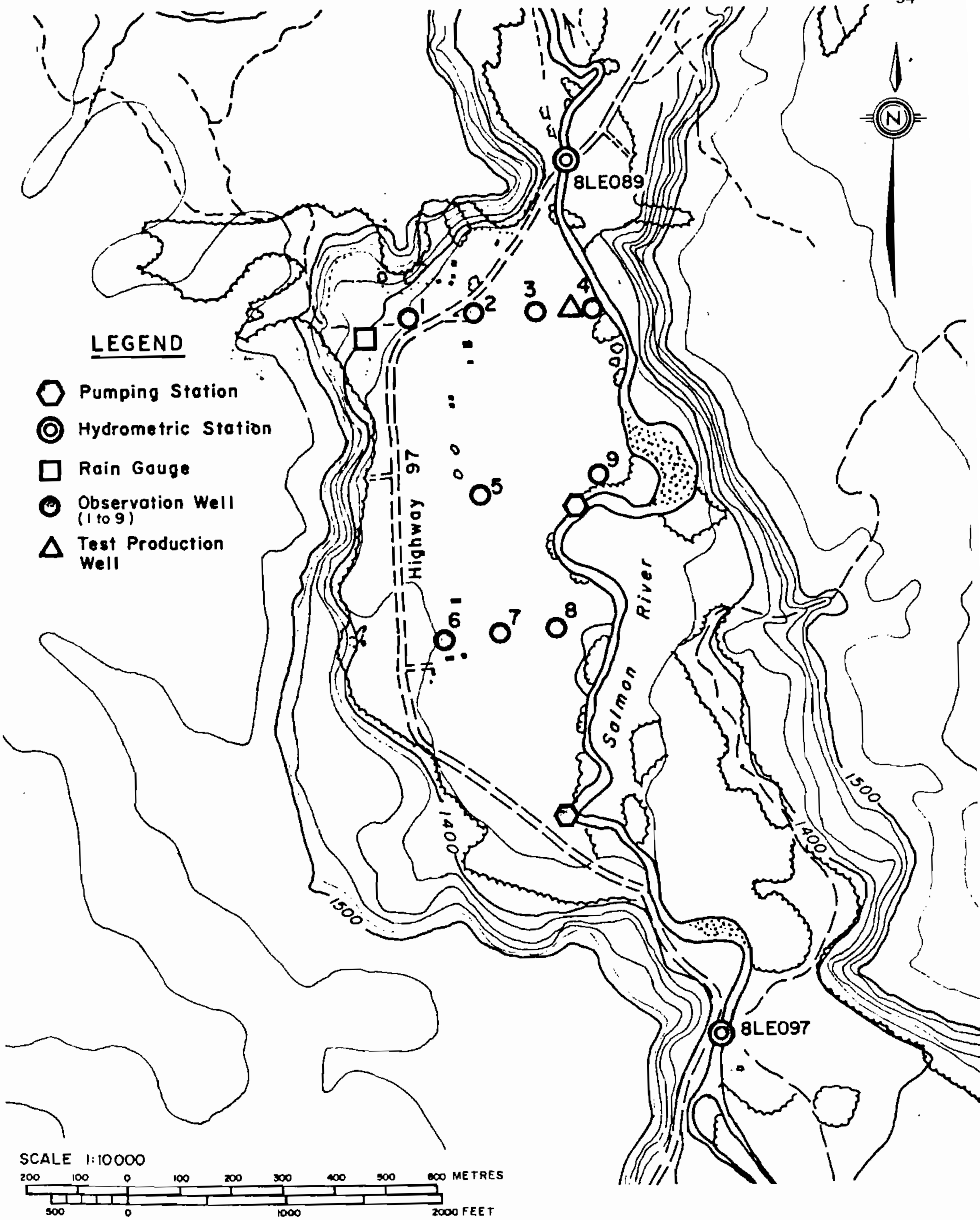

FIGURE 6.1

GROUNDWATER-RETURN FLOW MEASUREMENT SITE from precipitation, a hydraulic gradient towards the river is observed. The water table maps and observation well transmissivity tests also revealed a narrow zone of higher rate groundwater movement from the southeast corner of the farmfield in a northwest direction. This direction coincides with that of the upstream river channel, before it turns north parallel to the field site and broadens out parallel to the river. This narrow transitional zone could represent an old stream bed of highly permeable deposits which intercept the existing river channel and causes a direct loss of streamflow. The low flow regime analysis of Section 9 demonstrates a measured loss of inchannel flow from the gauging station (8LE097) upstream of the test site to the gauge (8LE089) downstream. A hydrograph analysis which shows a freshet peaking a few days earlier at the downstream station also demonstrates this loss.

Analysis of annual hydrographs of observation wells and the two hydrometric stations revealed a second, longitudinal groundwater zone which is directly influenced by the adjacent river channel, closely following its freshet flow pattern. A third, lateral zone was identified on the western edge of the site adjacent to valley side which acts as a source of groundwater. However, this groundwater movement is smaller in magnitude than that of the groundwater zone adjacent to the river and its peaks are flatter and occur later due to the latter's hydrologic barrier effects obstructing its groundwater flow.

In an apparent contradiction to definition of the groundwater zone adjacent to the river, a 25-hour pump test on the test well at the north end of the site revealed very little hydraulic continuity between the river and groundwater table. The cone of depression surrounding the test well showed very rapid expansion especially on the river side and total recovery time of 18 days was abnormally long. These observations suggest an adjacent impermeable stream bed which could be caused by siltation of the stream bed after freshet peaks as referred to in Section 6.1.

The experimental procedure used to determine return flow from irrigation water consisted of measuring the applied water, estimating the area of application and interpreting the response of well hydrographs. For the purposes of this exercise return flow (RT) was defined as the water table rise (WTR) times effective porosity (EP) divided by the depth of applied water (AW) or RT = (WRT)(EP)/AW. It should be stressed that the return flow analyzed here is that water contributing to storage of the aquifer, not that contributing directly to the base flow of the river as is commonly thought. The effective area of application was not measured but rather, inferred by analyzing the well hydrograph, and by making trial calculations using different numbers of "unit" areas which give different depths of applied water and, in turn, different return flow estimates. This was recognized as perhaps the largest source of error in calculations and more rigorous field observations of irrigation practise are planned for future data collection on the site. From the 23 irrigation peaks analyzed, groundwater return flow to the water table was estimated to be approximately 25% of applied water.

The third water balance component of the irrigation system, evapotranspiration (ET), was considered in the water balance equation, AW = ET + (WTR)(EP) + Losses, where AW is applied water including irrigation and precipitation over the effective area. Using 0.17 in/day maximum daily evapotranspiration (Reference 6) for alphalpha, the major crop of the study area, and considering the total duration of the irrigation hydrograph response some of the return flow figures were checked and were found to be approximately correct.* In order to obtain an accurate ET estimate, additonal field observations (during irrigation test trials) would have to include type of crop, its state of maturity, temperature and perhaps wind speed and humidity.

Recession of irrigation peaks was shown by well hydrographs to be rapid, two to five days within the zone of direct influence of the river regime (bank storage) and seven to fourteen days within the zone of indirect river influence. The amount of irrigation water added to groundwater storage (return flow in this case) to retard groundwater recession which follows river base flow recession is unknown but is considered minor in providing groundwater discharge to the river at this site. Under efficient irrigation conditions

*Consider the irrigation application of July 27 to August 3, 1975 at test hole #3 (Reference 2): using a 7-day duration and 30% porosity, ET + Losses = AW - (WTR)(EP) = 0.16 - (0.133)(0.3) = 0.12 ft/7 days = 0.20 in/day. If losses are 15%, ET = 0.17 in/day. RT = (WTR)(EP)/AW = (0.133)(0.3)/0.16 = 25%.

(such as recommended in Reference 4) when only the required amount of water is applied to satisfy the evapotranspirative demand of crops, there should be no return flow, even to the water table.

6.4 Groundwater Well Withdrawals

In contrast with the established licensing system of surface waters there is no licensing of subsurface water withdrawal by groundwater wells. Groundwater is an important component of the total flow regime of the Salmon River and any useage of this component deserves close attention. The Groundwater Section has compiled a list of groundwater wells in the Salmon River basin, shown in Table 6.1.

Table 6.1 SALMON RIVER BASIN GROUNDWATER WELLS

Region Between Mainstem Hydrometric Stations	Number of Wells		Total Irrigation Well Yield (cfs)
	Domestic	Irrigation	
Source to 8LE075	0	0	0.0
8LE075 to 8LE019	3	0	0.0
8LE019 to 8LE059	6	2	0.9
8LE059 to 8LE020	114	22	9.9
8LE020 to 8LE064	10	3	1.4
8LE064 to 8LEB08	18	3	1.4
8LEB08 to 8LE097	8	1	0.4
8LE097 to 8LE089	1	0	0.0
8LE089 to 8LE098	17	2	0.9
8LE098 to 8LE090	15	2	0.9
8LE090 to 8LE088	10	2	0.9
8LE088 to 8LE021	8	3	1.3
TOTAL	210	40	18.0
Approximate Individual Well Yield (Imp.gpd)*	500	240,000	0.45
Total Well Yield (Imp.gpd)	105,000†	9,600,000	18.0

*Domestic wells are rated at an average rate since useage of this type would be all year and approximately at a uniform rate. Irrigation wells are rated at a maximum rate since water withdrawals occur over the irrigation season and a maximum rate would be the most relevant one in a low flow water use component analysis. †(0.2 cfs)

In addition there is one municipal well, which supplies at least 150 homes in Salmon Arm, rated at approximately 100 Imperial gallons per minute or 0.3 cfs.

7. FISHERY SPAWNING REQUIREMENTS

7.1 Affected Fish Species

The Salmon River is used for spawning by two species of Pacific salmon, the coho and chinook (spring). Average time periods for the various stages of reproduction for these species are given in Table 7.1. These are the only historic runs to migrate directly to the Salmon River and since 1913 when the Hell's Gate blockade destroyed the sockeye and pink salmon runs to this river. In October and November, stray sockeye from overpopulated Adams River runs may appear in other tributaries of Shuswap Lake but are late in the season and therefore of no value for reproduction purposes (Reference 11). The Salmon River also supports trout and whitefish which are confined mostly upstream of Silver Creek due to high water temperatures downstream. No commercial value is attributed to these species for purposes of this study.

Table 7.1 AVERAGE TIME PERIODS FOR SALMON REPRODUCTION

Salmon Species	Approximate Times	Reproduction Stage			
		Upstream Migration	Spawning	Emergence & Rearing	Downstream Migration
Coho	Start	late September	early November	late April-early May	late May
	End	early November	late December	1 year later*	early June
Chinook (spring)	Start	mid July	late August	early April	late June
	End	late August	early October	late June	late July

*Coho remain in the stream for a full year during their rearing stage.

7.2 Representative Spawning Stations

In the Salmon River, salmon reproduce from the mouth to the railway bridge crossing above Falkland. Preferred spawning occurs in the 26 mile reach between the mouth of Silver Creek and the above railway bridge as shown in Figure 3.2. Seven representative spawning stations were chosen for monitoring by the Fish and Wildlife Branch and their relationship to hydrometric stations is discussed in Section 5.3.

7.3 Critical Hydraulic Characteristics at Spawning Stations

Hydraulic characteristics were determined by the channel survey (Section 5) at the seven fishery spawning stations. For each station, Appendix C lists hydraulic elements which include cross-sectional area (A), wetted perimeter (WP), hydraulic mean depth* (HD=A/WP) and channel width at various water levels which are designated by local elevations and gauge heights. Hydrometric characteristics derived from the main channel survey and subsequent streamflow measurements are also given in the form of curves where stage is plotted against area, velocity and discharge (Figure C.1). This information is necessary for water level and flow monitoring purposes as outlined in Section 10. The Fish and Wildlife Branch have established depth and velocity requirements for salmon reproduction purposes as listed in Table 7.2 following.

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*In regular shallow and wide channel cross-sections (e.g., in the Salmon River) the hydraulic mean depth or hydraulic radius is approximately the same as mean depth. The former depth is based on the wetted perimeter which includes the effects of slope changes and deeper pockets which may be missed or improperly weighted by regular interval depth soundings. In the case of deeper rectangular cross-sections with vertical ends the hydraulic mean depth is smaller than mean depth and would be a more conservative value. This study is however concerned with the former cross-sections.

Table 7.2 HYDRAULIC REQUIREMENTS FOR SALMON SPAWNING*

Hydraulic Characteristics		Salmon Species	
		Coho	Chinook
Preferred Velocity (fps)	min.	1.20	1.75
	max.	1.80	2.25
Preferred Depth (ft.)	min.	1.00	1.50
	max.	1.25	1.75
Critical Minimum Depth (ft.)		0.5	0.8
Critical Minimum Velocity (fps)		1.1	1.5

(Critical minimum swimming depth for both species is 0.5 feet)

Fishery station hydraulic characteristics, gauge heights, velocities and discharges corresponding to the above critical minimum depths and velocities have been extracted from Appendix C and are listed in Table 7.3. Flows which represent the limiting minimum values of 0.5 and 0.8 foot depths and 1.5 fps velocity have been plotted against channel length in Figure 9.2. The flow characteristics and gauge heights are actually those of the measurement section of the gauge that were transferred to that of the fishery station by assuming a common cross-sectional area. This is adequate for F1, F2, F3 and F7 but may not be for F4, F5 and F6 which are located 150, 1000 and 300 feet, respectively, from their gauges. These gauges (see Section 5.3) were installed for hydrometric feasibility which have better measuring sections and controls than the fishery locations. However, gauges are now installed at the fishery stations to evaluate the effects of their hydrometric stability and the transfer of flow characteristics between the adjoining gauges.

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*Fishery reproduction requirements were obtained by personal communications with S. J. MacDonald.

Table 7.3 KEY HYDRAULIC CHARACTERISTICS AT FISHERY STATIONS

Fishery Station	Hydraulic Mean Depth (ft)	Cross Sectional Area (ft^2)	Wetted Perimeter (ft)	Channel Width (ft)	Gauge Height (ft)	Mean Velocity (fps)	Discharg (cfs)
F1	0.5	22	42	42	0.8	0.9	20
	0.7	43	63	63	1.5	1.5	65
	0.8	49	64	63	1.7	1.6	80
	1.5	101	67	66	2.7	1.9	195
F2	0.5	14	27	27	(12.0)	(1.4)	(20)
	0.7	28	41	40	11.5	1.5	42
	0.8	37	48	47	11.3	1.6	60
	1.5	76	51	50	10.7	1.6	125
F3	0.5	9	17	17	0.9	1.1	10
	0.7	15	23	22	1.2	1.5	22
	0.8	20	25	24	1.4	1.7	35
	1.5	68	46	44	2.3	2.1	145
F4	0.5	17	34	34	14.1	0.7	12
	0.8	32	42	42	13.5	1.4	47
	0.8	34	42	42	13.5	1.5	50
	1.5	73	49	48	12.6	2.6	195
F5	0.5	19	38	38	0.8	0.9	18
	0.7	31	42	42	1.2	1.5	45
	0.8	36	44	43	1.4	1.7	60
	1.5	72	47	46	2.2	2.6	186
F6	0.5	19	37	37	-	-	-
	0.7	31	47	47	1.1	1.5	45
	0.8	41	50	50	1.6	2.8	110
	1.0	52	51	51	1.9	3.2	170
F7	0.5	18	36	35	(1.0)	(0.3)	(5)
	0.8	30	37	37	1.4	0.7	22
	1.4	56	40	39	2.1	1.5	90
	1.5	61	41	39	2.3	1.7	110

( ), flow characteristics are approximate.

\- , flow characteristics are not defined due to lack of low flow measurements.

7.4 Critical Salmon Reproduction Temperature Conditions

The Fish and Wildlife Branch has determined critical water temperature conditions for salmon reproduction (Reference 12). The following are stated to be optimum temperature ranges for salmonids:

Table 7.4 OPTIMUM TEMPERATURE RANGES FOR SALMONIDS

Cycle	Temperature			
	°C		°F	
	min.	max.	min.	max.
Migration	7.2	15.6	45	60
Spawning	7.2	12.8	45	55
Rearing	12.8	15.6	55	60

In general fish are able to sense temperature changes as small as 0.05°C (0.1°F) and successful salmon reproduction depends on a fairly rigid temperature range between 7 and 15°C. All species of migrating Pacific salmon tend to avoid temperatures at the mouth of a stream above approximately 15.5°C.

In August of 1975 the Fish and Wildlife Branch conducted a series of temperature readings at the seven designated fishery stations. Mean temperatures are listed below:

Table 7.5 FISHERY STATION WATER TEMPERATURES
August 1975

Station	F1	F2	F3	F4	F5	F6	F7
Temperature (°C)	N.A.	18.1	18.0	16.6	15.4	14.7	12.6

Table 7.5 shows that all stations except F7 (F1 data is not available) show monthly mean water temperatures above the upper limit spawning temperature of 12.8°C (Table 7.4), although spawning does not begin until late August and is not in full force until September (when the average air and water temperature at Salmon Arm is approximately 4°C cooler than in August). Three stations

have mean August temperatures above the upper limit migration and rearing temperature of 15.6°C, when chinook are normally migrating. Temperatures are observed to increase along the river channel towards the mouth where high temperatures could delay upstream migration and thus destroy the spawn.

7.5 Streamside Vegetation

Vegetation along stream banks is an important factor in the environment which surrounds the salmonid habitat. Vegetation helps to reduce water temperature by intercepting direct radiation from the sun. Overhanging vegetation is a natural habitat for terrestrial insects which provide two-thirds of the food for salmon. Streamside brush also acts as a natural barrier against predators and other disturbances. Conversely, streamside vegetation may form a source of debris from erosion during highwater which would create log jams and hazards to bridges and other inchannel structures. During their field observations in 1975 the Fish and Wildlife Branch recorded lower water temperatures where there was adequate vegetation compared with higher temperatures where there was little or no vegetation along stream banks. In general, streamside vegetation decreases along the Salmon River channel towards the mouth.

In its report (Reference 12) the Fish and Wildlife Branch has proposed a project of planting deciduous trees and shrubs along 21 miles of intermittent sections of Salmon River banks that are void of vegetation from the mouth to a half mile above the upper end of the spawning reach. Using a 50-foot interval (106 trees per mile) for approximately 40 miles (both banks) 4300 trees would be required. For five-foot trees at one dollar per foot, the total cost of materials is $21,500. Labour cost for three people, planting 100 trees each per day, for 15 days at five dollars per hour, 7½ hour day ($112.50/day) was estimated to be approximately $1700. Total cost would be $23,200.00. An alternative method would be to establish a 50-foot green strip along the river bank to provide shade through natural growth. This however may result in only intermittent growth and trees would take a long period to develop.

7.6 Channel Restrictions for Fish Access

The channel regime survey (Section 5.2) revealed shallow cross-sections in certain reaches of the lower Salmon River where the river is aggrading due to siltation. Typical sites are near the mouth and upstream of the gauge above Silver Creek. These sections have shallow depths at base flow and could impair access to migratory salmon that require a minimum of at least 0.5 feet (Table 7.2). Shallow water bodies also have a high heat absorption capacity from solar radiation which is again hazardous for fish reproduction (Section 7.4). Recommendations are proposed for corrective action for channel restrictions for fish access in Section 11.2.

8. LICENSED WATER WITHDRAWALS

8.1 Inventory of Water Licenses

An inventory of all water licenses within the Salmon River drainage basin was made to assess the effects of water withdrawals on the river regime. An accounting form was especially designed for listing licensed water use quantities in spatial order in conjunction with hydrometric gauge locations. Appendix D shows this form with every water license, up to the moritorium date of April 1, 1974, entered in an upstream to downstream order starting in the headwaters of the Salmon River. All relevant license information was extracted from stream registers, maps and files of the Water Rights Branch office in Victoria. Licensed quantities of consumptive (irrigation and domestic) use were subtotalled between mainstem gauges for comparison with flow data (Table 8.1). A half dozen irrigation licenses that were restricted for the freshet period only were noted in the license compilations. Complicated multiple diversion point coverage by the same license was interpreted to avoid double coverage and licensed quantities were entered in the position of diversion from the stream. The same reference numbers as used in Water Rights licensing records, were listed with license numbers which would give enough information for the user to answer possible detailed queries on any license.

8.2 Licensed Water Use Practise

Licensed water users in British Columbia are restricted to a total seasonal quantity for irrigation and a maximum daily rate for domestic purposes. There are no limits for maximum rates of irrigation diversion although the Water Act gives the Water Rights Regional Engineer a regulatory power in certain circumstances. Records of actual water withdrawal are extremely rare from individual water users and studies of irrigation usually resort to either licensed quantities or estimates of water duty applied to irrigated acreages. A number of reports have quoted monthly application rates of season irrigation diversion totals. The latest of these, Reference 10, was used to distribute the compiled seasonal licensed totals in Table 8.1 into monthly figures for the regime analyses of Section 9. The distribution used from Reference 10 was that quoted for the neighbouring Okanagan valley but the irrigation practises were assumed similar in the Salmon River valley. It should be noted that all of these water license useage analyses are subject to error since the pattern of actual water withdrawals is unknown and variable and the amount of water that a farmer applies to a field is open to speculation. Some licenses are not used to capacity while some may be overused. This variation tends to be compensating when total quantities are studied.

Table 8.1 WATER LICENSED FOR CONSUMPTIVE USE

Region Between Mainstem Hydrometric Stations	Licensed Water Consumptive Use		Accumulated Licensed Water Consumptive Use		Accumulated Irrigation Licenses Converted to Flows (cfs)			
	Irrigation Apr.-Sept. Totals (ac.-ft.)	Domestic Annual Totals (Imp.gpd)	Irrigation (ac.-ft.)	Domestic (Imp.gpd)	Annual	Apr.-Sept.	Aug.	Sept.
Source to 8LE075	0	0	0	0	0.0	0.0	0.0	0.0
8LE075 to 8LE063	676	0	676	0	0.9	1.9	2.7	0.0
8LE063 to 8LE019	941	1,000	1,617	1,000	2.2	4.5	6.6	2.7
8LE019 to 8LE059	2,119	17,500	3,736	18,500	5.2	10.3	13.5*	5.6*
8LE059 to 8LE020	7,853	44,450	11,589	62,950	16.0	32.0	44.2*	18.3*
8LE020 to 8LE064	1,575	45,000	13,164	107,950	18.2	36.4	50.6	20.9
8LE064 to 8LEB08	2,065	14,550	15,229	122,500	21.1	42.1	59.0	24.4
8LEB08 to 8LE097	501	0	15,730	122,500	21.8	43.5	61.0	25.2
8LE097 to 8LE089	104	0	15,834	122,500	21.9	43.8	61.4	25.4
8LE089 to 8LE098	1,034	13,500	16,868	136,000	23.3	46.6	65.6	27.1
8LE098 to 8LE090	716	16,000	17,584	152,000	24.3	48.6	68.5	28.3
8LE090 to 8LE088	652	3,500	18,236	155,500	25.2	50.4	71.2	29.4
8LE088 to 8LE021	2,781	90,200	21,017	245,700†	29.0	58.1	82.5	34.1

*Between 8LE019 and 8LE020 there are 724 acre-feet licensed for diversion during the freshet months. These have been excluded for August and September flow calculations.

†245,700 Imp.gpd ≡ 0.46 cfs

Appendix F of Reference 8 gives a monthly distribution of seasonal water licenses where 25% of the total diversion is used during August and 10% during September.

9. LOW FLOW REGIME ANALYSIS

9.1 Definition of Water Use and Channel Regime Components

The mainstem channel regime of the Salmon River was used as the basis for analysis of low flow. Conflict between water use components in the Salmon River basin arises during periods of low flow in late summer and early fall. The irrigation season, as defined by the Water Rights Branch, extends from April to September. The critical period during low flow for salmon reproduction, as outlined in Table 7.1, runs from approximately mid-July to late December (coho rear all year). Hence, the low flow regime analysis is focused on August and September, the overlapping period of irrigation and fishery use, but is also extended to October for future fishery observations. July is not considered a low flow month since its mean flows are more than twice those of August.

The mainstem channel regime (described in Section 5.1) was analyzed by identifying flow quantities of water use and regime components at representative gauged points along the channel from its mouth to its source. Designated tributaries and measuring points are shown on the channel profile curve of Figure 5.1. Variation of measured low flow along the channel is shown in the streamflow profile plot of Figure 9.1 (Salmon River streamflow survey described in Section 5.2 and measurements listed in Appendix B). Flow profiles for 1974 and 1975 are similar except for minor discrepancies at miles 7.5 and 18 (8LE089), the latter being attributed to metering difficulties in 1974.

An ideal low flow regime analysis requires a small time unit during the lowest period of base flow to evaluate the most critical conditions. A daily basis would be too small a unit to define a static streamflow regime (state at which streamflow does not vary with channel distance in a specified time) because of stream channel storage effects. A low flow season average August to October time unit would be too long because pronounced fow fluctuations would be omitted. The streamflow channel survey showed a variable mainstem flow pattern with some hydrometric stations decreasing and some increasing from one day to the next. Section 4.5 however, showed that a

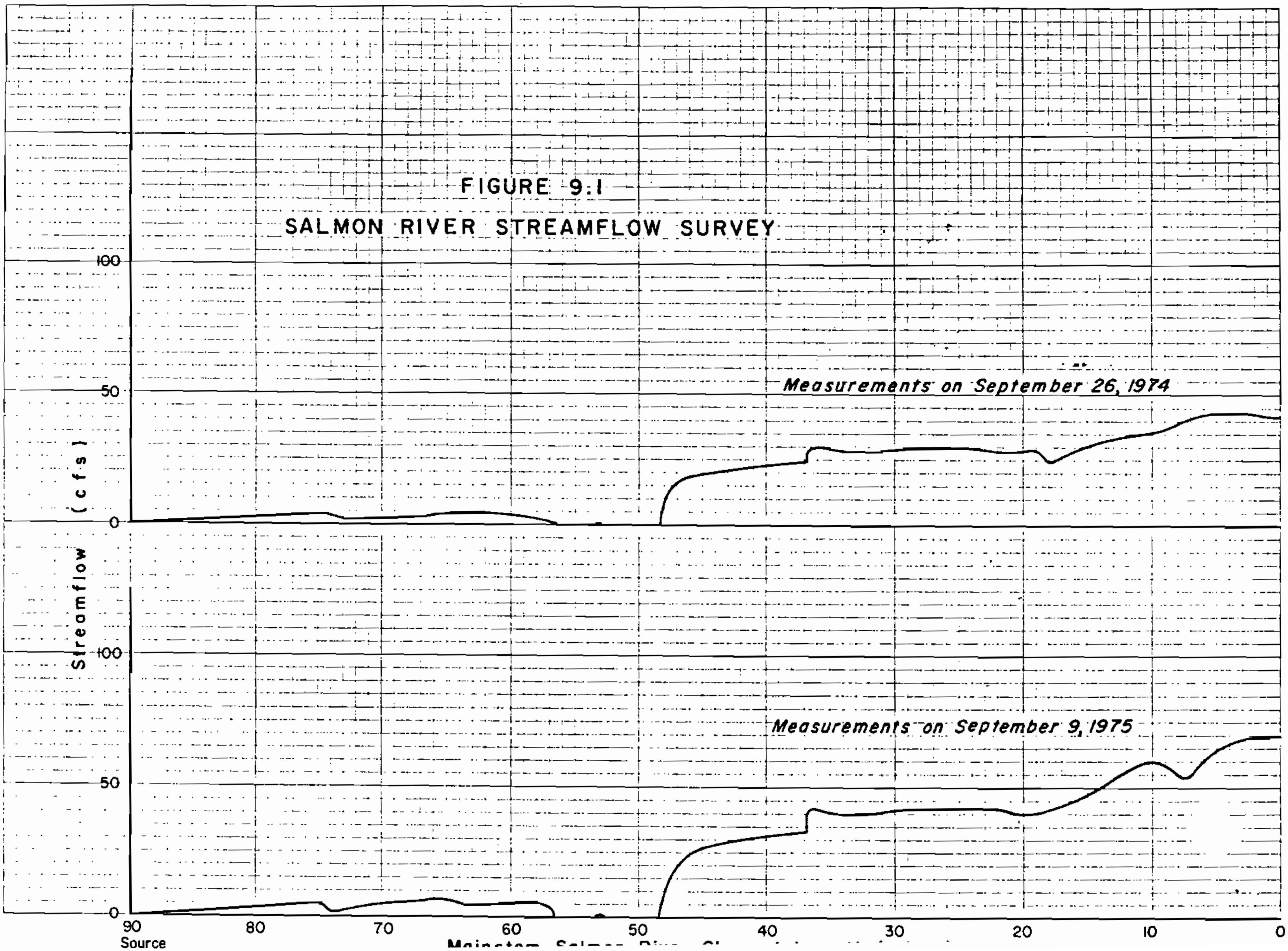


FIGURE 9:1

SALMON RIVER STREAMFLOW SURVEY

monthly time unit defines a stable channel regime with consistent monthly to annual streamflow ratios along the mainstem Salmon River. A monthly time unit is also convenient to define average conditions and to manage the water resource.

Streamflow channel components were defined as rates (cfs) for each of the mainstem hydrometric stations for analysis of the Salmon River streamflow regime profiles of the next section. Expected runoff was estimated for the 1975 water year and for the low flow months of August, September and October (Section 4.5). This expected flow is used as the upper profile curve to which all other flow and water use components are compared. In Figure 9.2 flows which represent the minimum hydraulic requirements for salmon reproduction (Table 7.2) were plotted against channel length. A composite salmon reproduction curve is derived to represent the limiting minimum flow requirements considering both the coho and chinook species. This curve represents the critical minimum depth of 0.5 feet for swimming in the none spawning reach between the mouth and mile 13 and the upper portions of critical minimum flow curves of 0.8 foot depth and 1.5 fps velocity for spawning in the spawning reach between miles 14 and 39. Accumulated licensed surface water withdrawals are presented in Table 8.1 in terms of flow units for annual and August and September totals.

9.2 Analysis of Channel Regime Components

The mainstem Salmon River channel flow regime was analyzed in plots of flow rates versus channel distance of the scale used in Figures 5.1 and 5.2. Expected runoff, measured runoff and net runoff (expected runoff minus licensed irrigation withdrawals) components are plotted in Figure 9.3 for the 1975 water year (November to October) and in Figures 9.4 to 9.6 for August, September and October, 1975. The variation and magnitude of measured annual flow between miles 40 and 60 is not known since this portion dries out in summer (Section 5.1) but its shape is interpreted from the base flow curves of Figure 9.1. For example, the flow conditions at miles 48 and 57 in September are known from the miscellaneous streamflow channel surveys and general summer observations.

FIGURE 9.2

MINIMUM SALMON RIVER FLOW REQUIREMENTS FOR SALMON REPRODUCTION

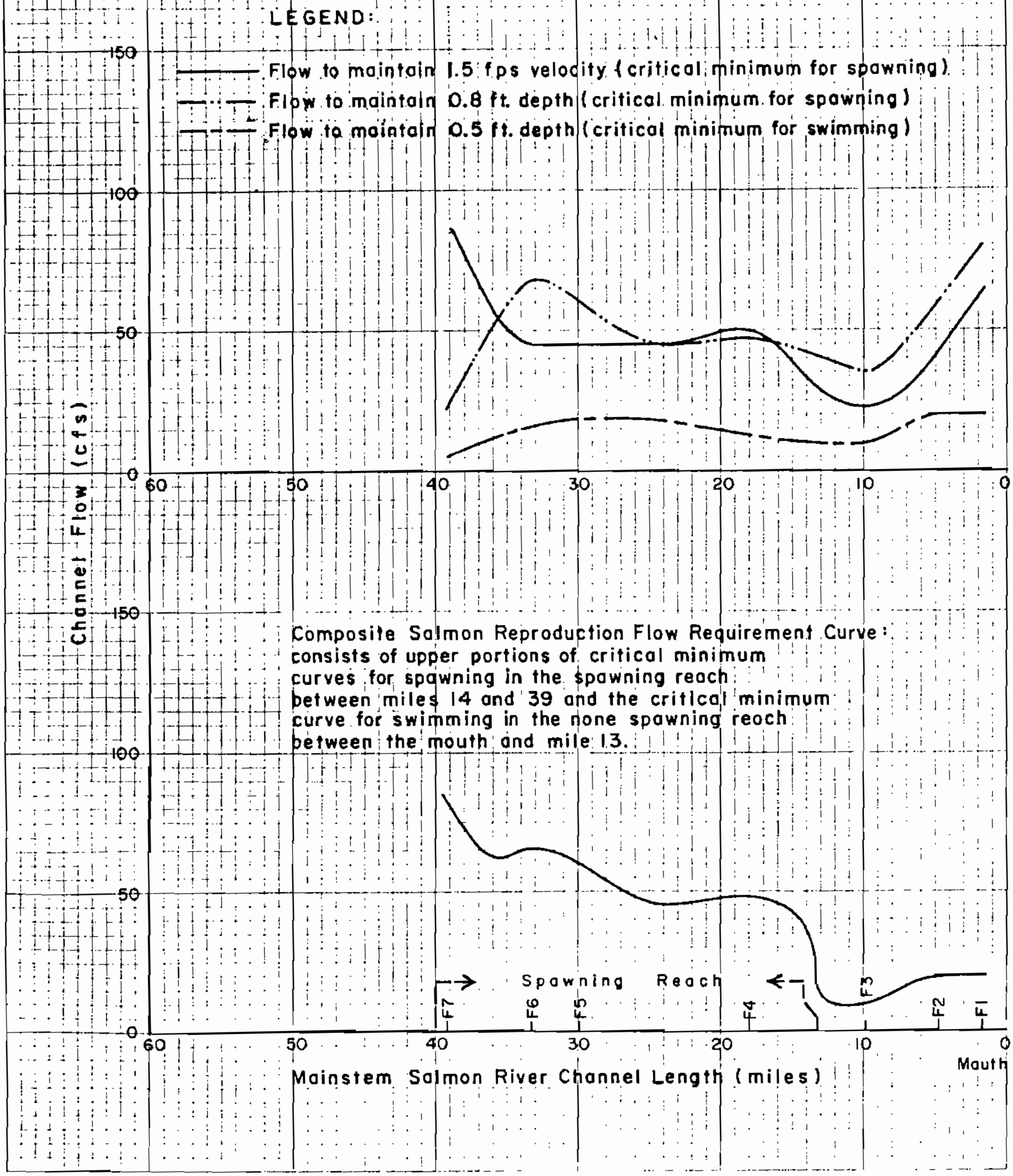
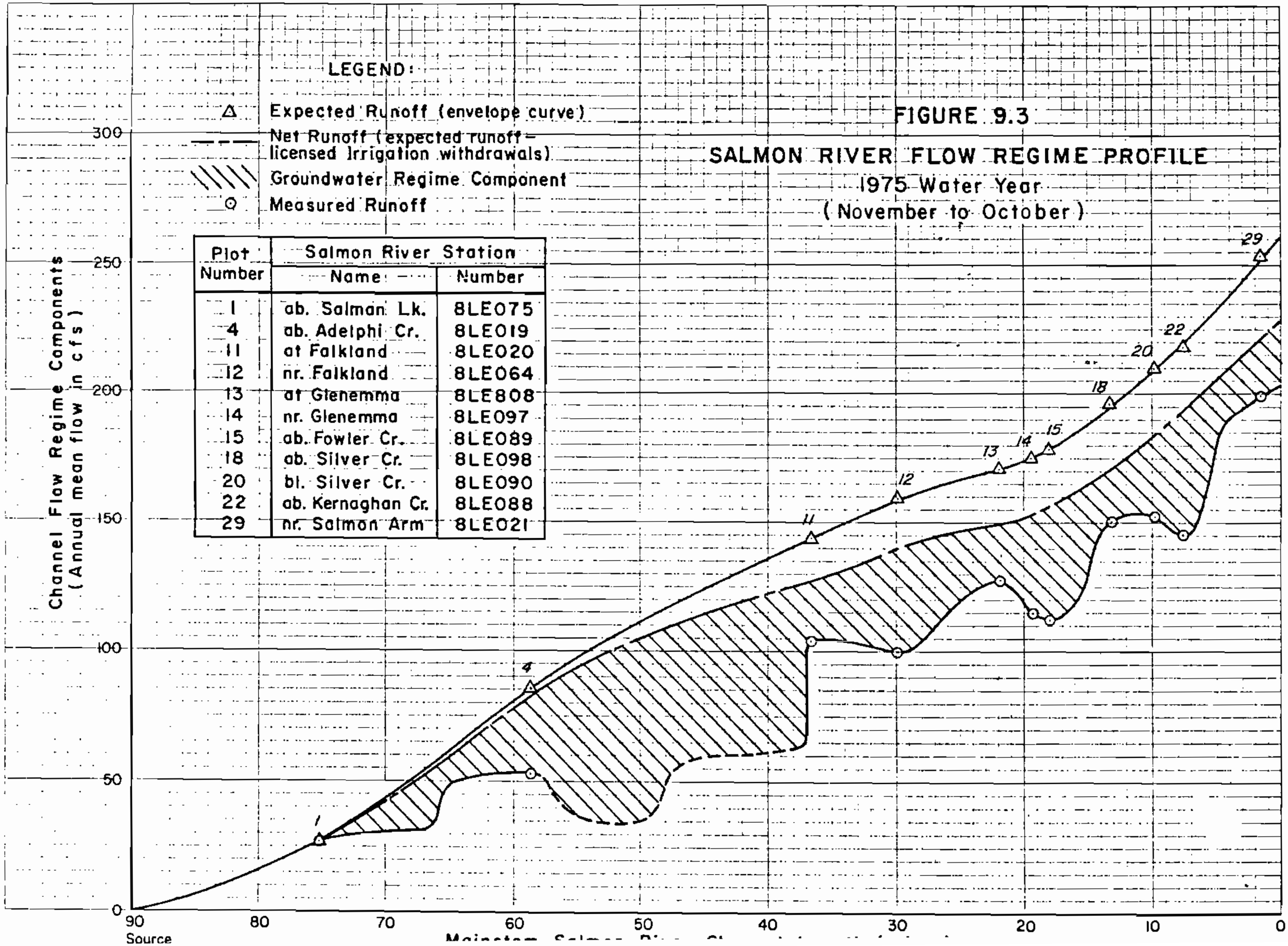


FIGURE 9.3

SALMON RIVER FLOW REGIME PROFILE

1975 Water Year
(November to October)



Plot Number	Salmon River Station Name	Salmon River Station Number
1	ab. Salman Lk.	8LE075
4	ab. Adelphi Cr.	8LE019
11	at Falkland	8LE020
12	nr. Falkland	8LE064
13	at Glenemma	8LE808
14	nr. Glenemma	8LE097
15	ab. Fowler Cr.	8LE089
18	ab. Silver Cr.	8LE098
20	bl. Silver Cr.	8LE090
22	ab. Kernaghan Cr.	8LE088
29	nr. Salmon Arm	8LE021

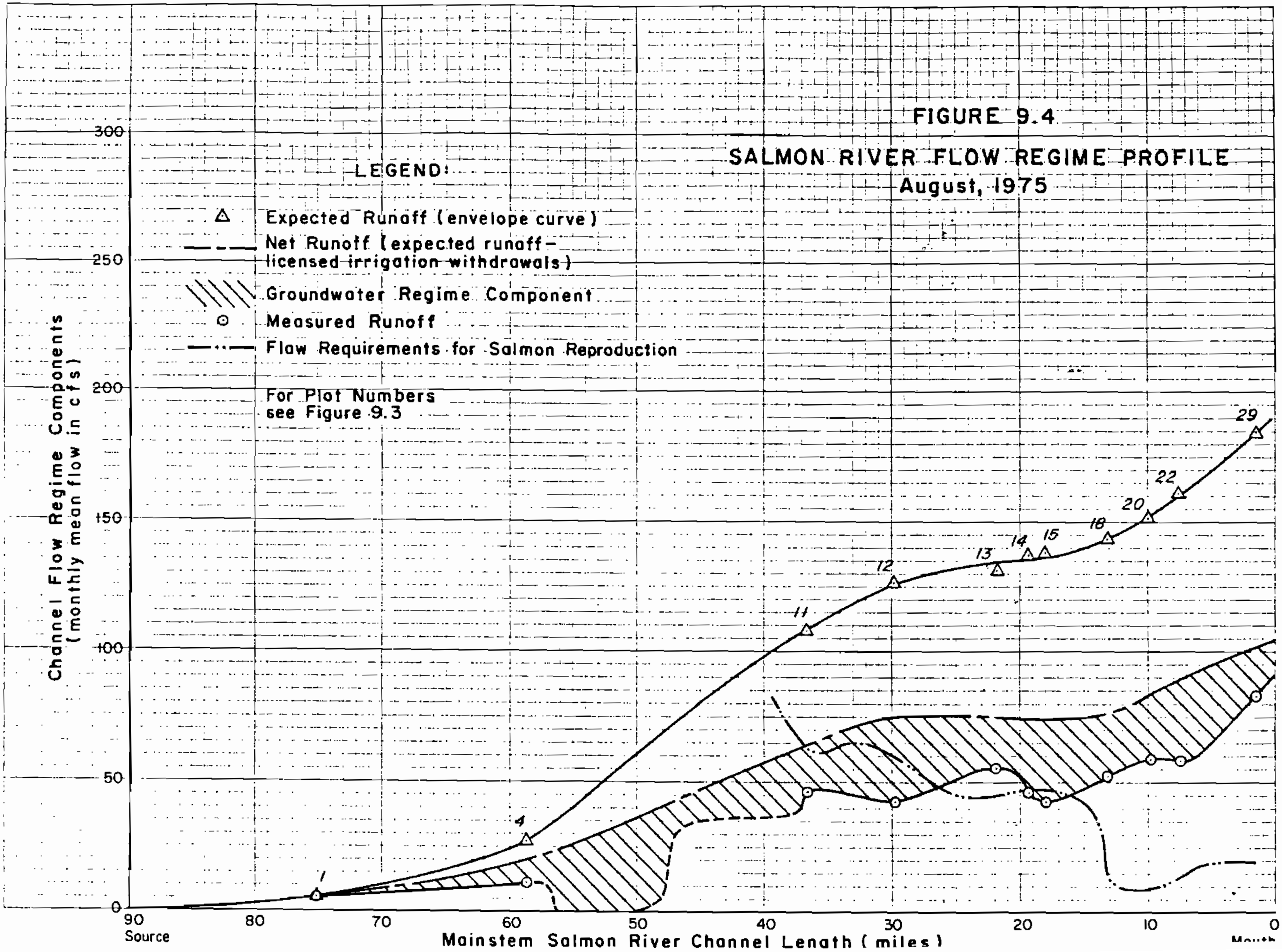


FIGURE 9.4
SALMON RIVER FLOW REGIME PROFILE
August, 1975
LEGEND:
Expected Runoff (envelope curve)
Net Runoff (expected runoff – licensed irrigation withdrawals)
Groundwater Regime Component
Measured Runoff
Flow Requirements for Salmon Reproduction
For Plot Numbers see Figure 9.3
Channel Flow Regime Components (monthly mean flow in c f s)
0
50
100
150
200
250
300
Mainstem Salmon River Channel Length (miles)
90 Source
80
70
60
50
40
30
20
10
0
1
4
11
12
13
14
15
18
20
22
29

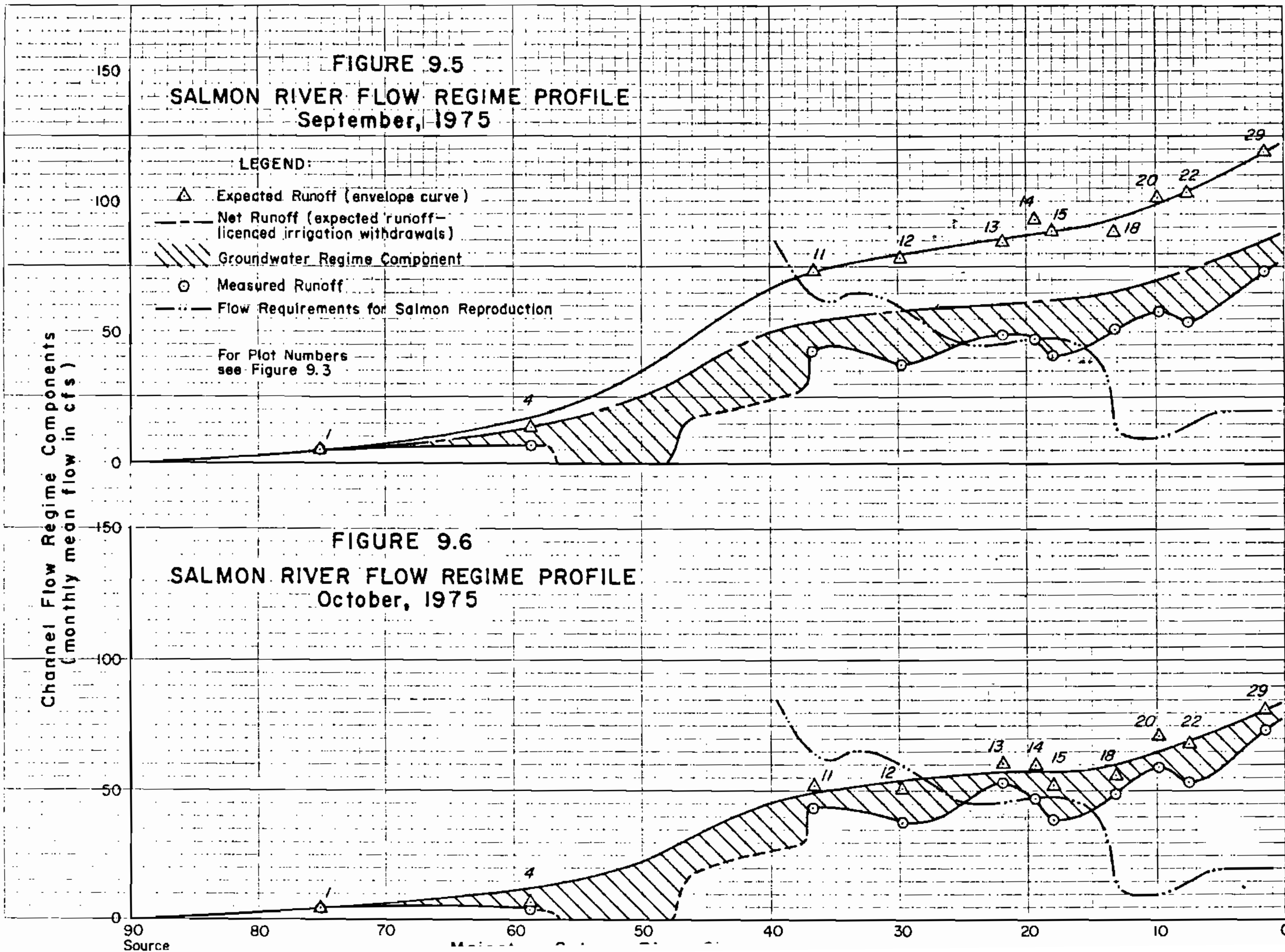


FIGURE 9.5
SALMON RIVER FLOW REGIME PROFILE
September, 1975
LEGEND:
Expected Runoff (envelope curve)
Net Runoff (expected runoff-licenced irrigation withdrawals)
Groundwater Regime Component
Measured Runoff
Flow Requirements for Salmon Reproduction
For Plot Numbers see Figure 9.3
FIGURE 9.6
SALMON RIVER FLOW REGIME PROFILE
October, 1975
Channel Flow Regime Components (monthly mean flow in cfs)
150
100
50
0
90
80
70
60
50
40
30
20
10
0
Source

The groundwater regime component is defined as the portion (cross-hatched) between curves of measured and net runoff. The vertical difference between these two curves at any point along the horizontal axis gives an estimate of the longitudinal groundwater flow. An examination of this component in the four figures shows that its shape is consistent and its magnitude decreases slightly with decreased channel flow as discussed in Section 5.1. The maximum groundwater flow indicated in Figure 9.3 appears to be approximately 70 cfs in the Westwold aquifer (Reference 13 quotes a 40 cfs infiltration value). Since there are no irrigation withdrawals in October, Figure 9.6 shows that the expected and net flow curves are coincident. The measured flows of September and October are similar. The resultant groundwater component for October is only slightly smaller than September and when Figures 9.3 and 9.4 are compared, it becomes apparent that the groundwater component decreases with decreased flow. Since errors in this analysis could range from ±5 to ±10 cfs the conclusion is that the net runoff curve is approximately correct in relation to the measured runoff curve and that the designated groundwater regime should also be approximately correct. This information is not used in a quantitative sense in the following determinations of water excess or deficit.

The composite flow requirement curve for salmon reproduction (Figure 9.2) was used for August, September and October. From the mouth to mile 13, the start of the spawning reach, this flow represents the critical minimum requirement of 0.5 feet depth for swimming therefore precludes flow conditions for any spawning. A comparison between the minimum fishery requirement curve and the measured flow curve shows the excess water available for irrigation withdrawal. A water budget along the mainstem channel is shown in Table 9.1 for August and September, 1975 and Table 9.2 for average and below average conditions. Table 9.1 shows that for August, 1975 available excess water averages 25 cfs for a channel distance from the mouth to mile 26 and 43 cfs, from the mouth to mile 14. For September, 1975 the excess is 40 cfs from the mouth to mile 14, only. Table 9.2 shows that for an average August flow the excess water would average 32 cfs and for an average September, 31 cfs, both from the mouth to mile 14. Using the 32 cfs August

Table 9.1 SALMON RIVER EXCESS WATER

1975 Summer Low Flow Conditions (cfs)

Mileage	August, 1975				September, 1975			
	Net Flow	Channel Flow	Fishery Requirement	Flow Difference	Net Flow	Channel Flow	Fishery Requirement	Flow Difference
(F1) 1.5	102	83.7	20	63.7	85	73.2	20	53.2
2	101	80	20	60	84	72	20	52
4	97	70	20	50	80	64	20	44
6	93	60	18	42	77	57	18	39
8	88	58	13	45	73	54	13	41
10	83	58	10	48	70	57	10	47
12	78	55	10	45	67	53	10	43
14	76	50	37	13	65	48	37	11
16	75	46	45	1	63	43	45	-2
(F4) 18	75	43	48	-5	62	41	48	-7
20	75	52	47	5	62	49	47	2
22	75	55	45	10	61	49	45	4
24	76	53	45	8	60	47	45	2
26	76	49	48	1	60	43	48	-5
28	75	45	54	-9	59	40	54	-14
30	75	43	60	-17	58	38	60	-22
32	72	44	65	-21	57	41	65	-24
34	70	47	65	-18	56	44	65	-21
36	66	47	63	-16	55	44	63	-19
38	62	38	73	-35	52	27	73	-46
(F7) 39	60	37	80	-43	51	25	80	-55
Avg. 2-14	88.0	61.6	18.3	43.3	73.7	57.9	18.3	39.6
Avg. 2-26	82.2	56.1	31.2	24.9				

Table 9.2

SALMON RIVER EXCESS WATER

Average and Below Average Summer Low Flow Conditions (cfs)

Mileage	Average August			Average September		August 90% of Time		September 90% of Time		Lowest Recorded 7-Day Low Flow	
	Channel Flow	Fishery Requirement	Flow Difference	Channel Flow	Flow Difference	Channel Flow	Flow Difference	Channel Flow	Flow Difference	Channel Flow	Flow Difference
(F1) 1.5	68.5	20	48.5	61.8	41.8	37.5	17.5	33.5	13.5	25.6	5.6
2	65	20	45	61	41	36	16	33	13	24	4
4	57	20	37	54	34	31	11	29	9	21	1
6	49	18	31	48	30	27	9	26	8	18	0
8	47	13	34	46	33	26	13	25	12	18	5
10	47	10	37	48	38	26	16	26	16	18	8
12	45	10	35	45	35	25	15	24	14	17	7
14	41	37	4	41	4	22	-15	22	-15	15	-22
16	38	45	-7	36	-9	21	-24	20	-25	14	-31
(F4) 18	35	48	-13	35	-13	19	-29	19	-29	13	-35
20	43	47	-4	41	-6	24	-23	22	-25	16	-31
22	45	45	0	41	-4	25	-20	22	-23	17	-28
24	43	45	-2	40	-5	24	-21	22	-23	16	-29
26	40	48	-8	36	-12	22	-26	20	-28	15	-33
28	37	54	-17	34	-20	20	-34	18	-36	14	-40
30	35	60	-25	32	-28	19	-41	17	-43	13	-47
32	36	65	-29	35	-30	20	-45	19	-46	13	-52
34	38	65	-27	37	-28	21	-44	20	-45	14	-51
36	38	63	-25	37	-26	21	-42	20	-43	14	-49
38	31	73	-42	23	-50	17	-56	12	-61	12	-61
(F7) 39	30	80	-50	21	-59	16	-64	11	-69	11	-69
Avg. 2-14	50.1	18.3	31.8	49.0	30.7	27.6	9.3	26.4	8.1	18.7	0.4

flow as the limiting factor this would allow an additional April-September seasonal irrigation water license diversion of 7800 acre-feet in an average runoff season. This calculation is based on Reference 10 which distributes the six-month total volume into partial totals of 25% for August and 10% for September.

In any future low flow water use planning it is desirable to consider below normal flow conditions. Low flow frequency curves were drawn for Salmon River at Salmon Arm (8LE021) for August, September and 7-day average low flows for June to September*, based on 27 years of record (Figure B.13 of Appendix B). These curves were used to extrapolate mainstem channel flow curves in Figure 9.7 for average conditions and 90% water excess conditions for August and September and for an excess based on the lowest 7-day average low flow on record (8LE021). The results of the channel water budget in Table 9.2 show that from the mouth to mile 14, 9 cfs in August, 8 cfs in September or 2300 acre-feet seasonal diversion volume is available as excess water 90% of the time. For the lowest 7-day low flow on record, the water budget shows that 17 out of 100 years (Figure B.13) no excess water would be available for 7 days.

It should be noted that return flow is not considered in excess water calculations since ideal conditions are assumed (perfectly efficient irrigation water application) as discussed in Section 10.3. Current irrigation withdrawals from the Salmon River and its return flow are accounted for by the measured flow which is the net flow subsequent to all external effects on the river system. Excess water is then the difference between the measured and fishery requirement flow curves. Return flow from over-irrigation could occur from any additional future irrigation withdrawals and would increase directly with the amount of over-irrigation.

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*In the Salmon River basin, the lowest flows occur in winter but 8LE021 has seasonal records only up to 1973. A longer term station is the Salmon River at Falkland (8LE020) with 33 years of continuous record. Using it as an index of comparison for winter low flows, References 4 and 5 show that for a 20-year return period 8LE020 has an annual 7-day low flow of 10 cfs compared with a June-September 7-day low flow of 20 cfs.

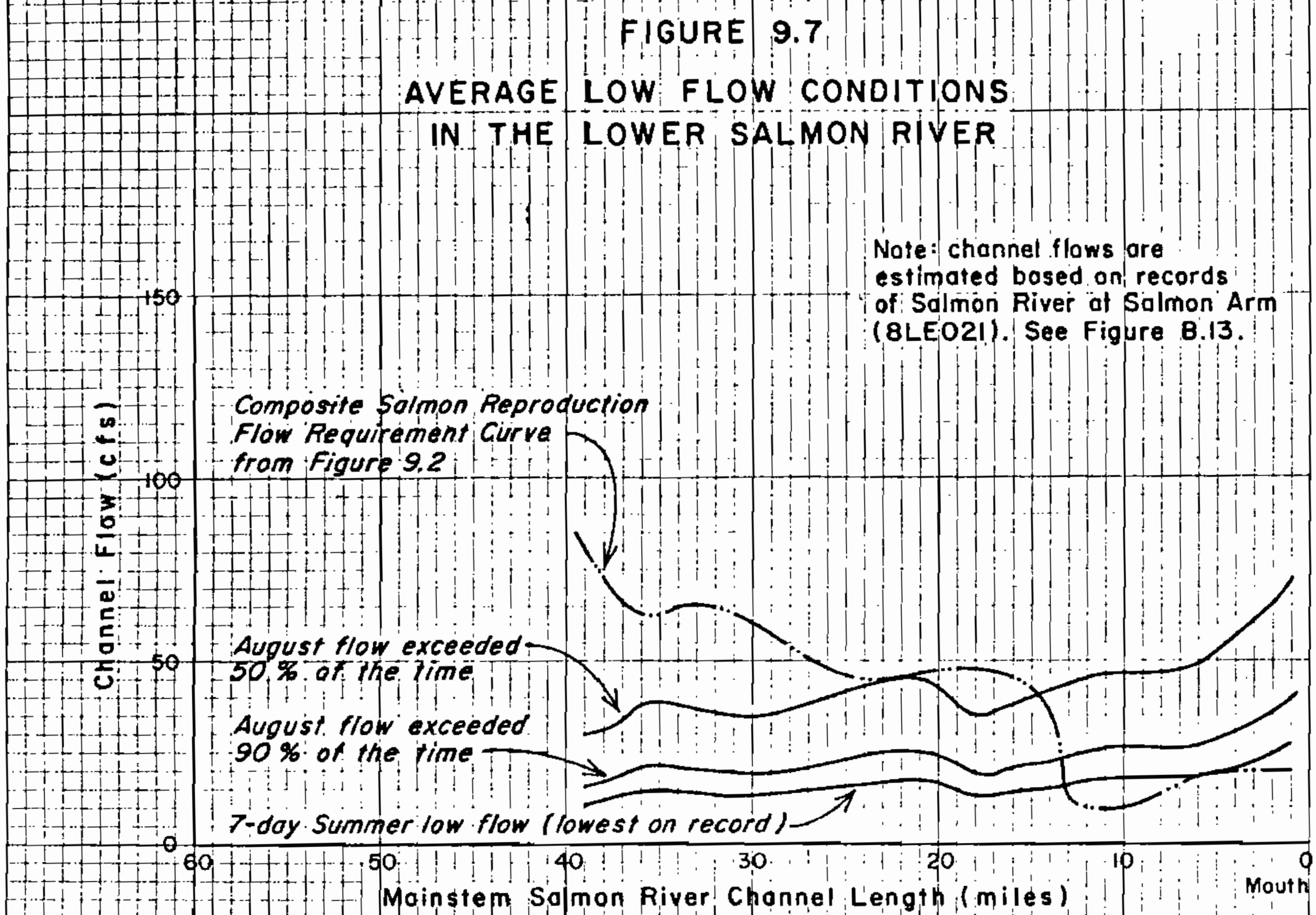


FIGURE 9.7
AVERAGE LOW FLOW CONDITIONS
IN THE LOWER SALMON RIVER
Note: channel flows are
estimated based on records
of Salmon River at Salmon Arm
(8LE021). See Figure 8.13.
Composite Salmon Reproduction
Flow Requirement Curve
from Figure 9.2
August flow exceeded
50 % of the time
August flow exceeded
90 % of the time
7-day Summer low flow (lowest on record)
Channel Flow (cfs)
150
100
50
0
60
50
40
30
20
10
0
Mouth
Mainstem Salmon River Channel Length (miles)

10. REGULATION OF CONFLICTING IN-CHANNEL WATER USES

10.1 Reference Hydrometric Stations

Any regulation of flow using designated fishery stations will have to be referenced to adjacent hydrometric stations with stable flow controls and established rating curves. Such reference stations are discussed in Sections 3.5 and 7.3 and are listed below in Table 10.1. Hydraulic conditions (gauge height, velocity and discharge) to meet requirements of the composite salmon reproduction curve of Figure 7.1 were extracted for each fishery station from Figure C.1. These conditions represent flows to maintain 0.8 foot depth and 1.5 feet per second velocity, both critical minimums, in the spawning reach of mile 14 to 39 from the mouth and 0.5 foot critical minimum swimming depth in the none spawning reach from the mouth to mile 13. The minimum spawning criteria are for chinook salmon since coho salmon reproduction requirements are not as high and would be met by those for chinook. Some of the flow characteristics may be revised, however, based on future measurements.

Table 10.1 REFERENCE HYDROMETRIC STATIONS FOR FISHERY STATION MONITORING

Hydrometric Station		Fishery Station	Hydraulics for Maintaining Composite Curve of Figure 7.1		
Number	Name		Gauge Height (ft)	Velocity (fps)	Discharge (cfs)
8LE021	Salmon R. nr. Salmon Arm	F1	0.8	0.9	20
		F2	12.0	1.4	20
8LE090	Salmon R. bl. Silver Cr.	F3	0.9	1.1	10
8LE089	Salmon R. ab. Fowler Cr.	F4	13.5	1.5	48
8LE064	Salmon R. nr. Falkland	F5	1.4	1.7	60
		F6	1.3	2.0	65
		F7	2.1	1.5	80

10.2 Water Level Monitoring During Critical Low Flow Periods

Accurate monitoring of critical low flow characteristics at fishery stations will require future field observation, testing and continued hydrometric evaluation as regulation continues. Stage-discharge curves will have to be maintained by the Hydrology Division to monitor changes in flow conditions at the gauges. Fish and Wildlife Branch personnel and/or paid local observers will have to monitor water levels at frequent intervals (two or three times per week) when critical low flow conditions are approached.

10.3 Regulation of Licensed Water Withdrawals

From the analyses of Section 9.2 (Table 9.2) it appears that for average flow conditions approximately 32 cfs in August or 7800 acre-feet (April-September total) are available for additional irrigation water withdrawal from the Salmon River up to 14 miles from the mouth. During lower flow conditions (water available 90% of the time) approximately 9 cfs in August or 2300 acre-feet (April-September) are available. However, these results should be viewed as preliminary, since only the absolutely lowest critical depth for salmon swimming access is considered in the non-spawning reach where hydraulic characteristics at fishery stations are not perfectly defined. Any future water licensing should be done in a conservative manner, increasing water licenses in partial amounts (e.g., starting with an initial total quota of 2300 acre-feet in the non-spawning reach) until hydraulic conditions at fishery stations are more precisely defined and the effects of the critical minimum spawning conditions assumed in this report have been ascertained as more data is collected and experience is achieved. Future water licensing will have to be restricted or cancelled temporarily when critical flow conditions are approached. In this case the Fish and Wildlife Branch would monitor fishery stations F1 to F4 and would notify the Water Rights Regional Engineer for appropriate action, e.g., temporarily cancel water licenses starting with the latest date of priority so that flow conditions are maintained to preserve minimum salmon reproduction requirements. In general, this procedure should be extended to the spawning reaches upstream of F4 where a water deficit exists in average conditions. As an aid to this type of water management, the applicability of volume runoff forecasting should be investigated.

The granting of new water licenses should be viewed as a last step in water resource management of the Salmon River basin. Water resource management must include a broader view in resource utilization and existing water use practise must be examined before efficient management can proceed. A thorough review of actual water use and licensing should precede any change of the water use in the Salmon River basin. Section 8.2 stated that the actual quantities of licensed water withdrawal are unknown. A field survey of actual withdrawals will have to be made (similar to that of Reference 8) but even then it may not prove conclusive since farmers do not measure their diversions. On the basis of this survey, unused water licenses could be cancelled. The remaining licenses could be restricted to a total seasonal quantity and monthly rates of withdrawal according to the area of application, type of crop and its evapotranspirative demand (Reference 6) and irrigation frequency. Diversion pipes could be equipped with flow meters (in the beginning for at least the new licensees) for regulation purposes. The Provincial Government could install and operate such meters and then recover their costs through license fees (partially contributed by fishery agencies). This practise would theoretically use the water efficiently and would not over-irrigate to produce return flow (Section 6.3). Such a water license survey would also include a review of the current licenses and a recompilation of the consumptive use subtotals (Appendix D) along the mainstem reach of the Salmon River. Since the groundwater regime forms an interdependent relationship with the surface water in the Salmon River basin a system of groundwater licensing similar to surface water licensing should be established.

11. OTHER RELEVANT WATER MANAGEMENT CONSIDERATIONS

11.1 Storage Potential in the Salmon River Basin

Reservoir storage development in the Salmon River basin has been very limited inspite of high irrigation withdrawal. Storage potential exists in the headwaters region of Salmon River (e.g., upper Weyman Creek, Salmon and Rush Lakes) but has been virtually ignored by agricultural interests because of high channel conveyance losses to downstream diversion sites of Westwold valley and below. Licensed storage in this region amounts to only 2040 acre-feet. The remaining Salmon River licensed storage (Reference 7) is 420 acre-feet in Ingram Creek, 303 acre-feet in Spa Creek and Wallensteen Lake (roughly 25 acres area). Storage potential of other lakes are Salmon Lake (370 acres), Rush Lake (166 acres), neighbouring Index Lake (205 acres) and, tributary to Bolean Creek, Blair Lake (180 acres) and Bolean Lake (160 acres).

Any future storage development upstream of Westwold may not directly enhance baseflow downstream since channel flow would be lost to infiltration. However it would increase groundwater storage in the Westwold valley and thus could increase downstream base flow indirectly. On a short-term basis this transmission of base flow through the Westwold aquifer would not be practical for augmenting flow in the salmon spawning reaches below Falkland. Storage from Blair and Bolean Lakes should directly affect the flow downstream in the Salmon River. Section 9.2 indicated a shortage* of Salmon River base flow from approximately 15 miles above the mouth to Falkland (Figure 5.1) for salmon reproduction purposes. Storage on Bolean Creek and perhaps a diversion of Spa Lake into Blair Lake could be developed to enhance base flow in this reach for the benefit of fishery reproduction.

Since the scope of this report is confined to low flow water resource management, the reference to the above storage potential development is for augmenting flows for agricultural and fishery interests. A complementary function of storage development is flood control which is also an important water resource management function in the Salmon River basin. Storage

*This storage was not calculated for the low flow months of August and September, the low flow study period. A detailed storage requirement study would have to include low flow winter months as well.

development would then be multipurpose with interception and storage of flood flow for later release to augment low flow for agricultural and fishery interests. Costs of storage development could be allocated to the three interests (considering flood control) according to the respective benefits accruing to each (see Appendix E).

11.2 Corrective Action for Channel Restriction of Fish Access

The channel regime survey (Section 5.2) revealed two reaches on the Salmon River, near the mouth and upstream of the mouth of Silver Creek, where siltation restricts the flow and which could impair access to migratory fish. Such channel conditions could be improved by direct dredging of the stream bed or by bank improvement. A popular bank improvement method is by use of gabions (Reference 14) which are rectangular wire mesh baskets placed in the stream bed and filled with rocks. Various size meshes are available and depending on their method of placement and orientation different conditions of channel flow can be obtained. Advantages of this method are low cost, ease of installation, flexibility, durability, permeability and natural appearance.

12. CONCLUSIONS AND RECOMMENDATIONS

This study attempts to resolve the conflict between two major water users, agriculture and salmon fishery, by quantitatively assessing their water requirements in relation to surface and subsurface flow components within the total flow regime of the Salmon River basin. The Salmon River has a complex flow regime due to a highly permeable valley floor of unconsolidated glacial deposits and extensive irrigation withdrawals. Two hydrologic zones were defined, a low runoff southwestern zone and a moderate runoff northeastern zone. In average years in the wet zone the elevation of zero runoff was defined to be approximately 2000 feet above which approximately 8 to 20 inches of surface runoff occurs and in the dry zone, 3500 feet, above which approximately 5 to 7 inches surface runoff occurs. A streamflow regime analysis showed that approximately between 1/3 and 1/2 of the water available in the

Salmon River in the 1975 low flow months is used by licensed water diversions. In average summer low flow months, minimum salmon reproduction requirements (depths and velocities) are surpassed by approximately 30 cfs from one to 14 miles from the mouth (the non-spawning reach) but are deficient from 15 to 39 miles from the mouth, in the spawning reach (no salmon reproduction occurs above 40 miles above the mouth). It was estimated that during average conditions up to approximately 7800 acre-feet (based on 32 cfs withdrawal during August) are available in the water surplus reach for future restricted water licenses. These estimates of surplus flow should be viewed as preliminary since they are based on critical minimum depths required for salmon swimming access downstream of the spawning reach and extra water should only be licensed partially until the effects of the critical minimum spawning conditions assumed in this report have been ascertained with more data and resource management experience. A number of groundwater flow calculations were made which compared favourably with observed groundwater losses (e.g., 20 cfs from the Westwold aquifer). At the groundwater well test site return flow to the water table was determined to be approximately 25% of the applied irrigation water. Water temperature conditions in the spawning reaches were observed to be adverse for fish reproduction. Some possible channel restrictions for migrating fish were also observed.

Based on these findings and information collected to date, the following recommendations are made for a water resources management plan in the Salmon River basin. This plan is designed for the ideal situation in which each component is operating at its peak efficiency, including application of irrigation water, only in the amount that is demanded by evapotranspiration. Hence return flow was not considered in excess water calculations. It may also be necessary to rewrite the water act to accommodate some of the steps, certainly to enforce groundwater licensing. These are only recommendations and the onus is on the appropriate authorities to formulate a management plan.

The following steps should constitute an efficient water resources management plan for the Salmon River basin.

1. There appears to be approximately 7800 acre-feet (April-September total) additional water available for irrigation water withdrawal during average flow conditions in the Salmon River between one and 15 miles from the mouth. However, irrigation diversion up to 2300 acre-feet should be conditionally licensed (available 90% of the time) until more data is collected and actual field experience is gained to ascertain the fishery requirement criteria and revise the water surplus estimates.

2. Establish a regulation program whereby water licenses are restricted or temporarily cancelled (e.g., starting with the latest date of priority) in the Salmon River reach between miles one and 15 from the mouth when critical low flow conditions are approached. Such a program should also be investigated for established water licenses upstream of mile 15 in the spawning reach where water deficiencies exist for salmon reproduction.

3. Monitor water levels at fishery stations F1 to F4 during low flows (Fish and Wildlife Branch or water bailiff) and notify the Water Rights Branch when critical conditions are approached. Investigate the applicability of volume runoff forecasting to aid in prescheduling water level monitoring.

4. Maintain stage-discharge curves at stream gauges of fishery stations and review the accuracy of hydraulic and flow characteristics by channel and flow measurements (Water Investigations Branch). This should be emphasized during future critical low flow periods. Such information should lead to more precise water quantities for both fishery requirements and agricultural useage.

5. Retain the established supplementary hydrometric stations on Weyman (8LE095), Ingram (8LE008), Bolean (8LE094), Fowler (8LE096), Kernaghan (8LE091), Gordon (8LE092) and Palmer (8LE093) Creeks and Salmon River stations above Adelphi (8LE019), near Falkland (8LE064), above Fowler Creek (8LE089) and below Silver Creek (8LE090). These stations should be retained for hydrologic, water supply assessment and administrative purposes or until such time when their utility can be accurately assessed. Such a review should be conducted annually. Establish a hydrometric station at miscellaneous site M11 and a series of groundwater wells in the Westwold aquifer for future hydrologic studies.

6. Review and conduct a field survey of licensed water withdrawals to determine or estimate the actual quantity withdrawn. Cancel unused water licenses.

7. Limit each irrigation licensee to the total seasonal quantity licensed and to pre-determined maximum monthly rates, e.g., for his area irrigated, type of crop, its evapotranspirative demand and irrigation frequency. Both average and dry years should be considered.

8. Establish a licensing system for groundwater useage similar to surface water licensing.

9. Establish a metering system for both surface and subsurface licensed withdrawals. In the initial stages this could be imposed first on new irrigation licenses. On a long-term approach all irrigation licenses would have to be metered for efficient water resource management. Costs of meter installation and data collection could be at first assumed by the Water Rights Branch but then recovered through fees from licensees and fishery agencies. This type of approach is required to insure a uniform standard of license regulation and data collection.

10. Implement the streamside vegetation program as proposed in the Fish and Wildlife Report (Reference 12).

11. Investigate the development of headwater storage on Bolean Creek and the diversion of Spa Lake into Blair Lake as a supplement to augment flows between 15 and 40 miles from the mouth of Salmon River for fishery purposes.

12. Review the engineering feasibility of corrective action to eliminate channel restrictions for fish access.

13. Conduct an economic analysis of the Salmon River basin for an ideal water management plan which would result in efficient and equitable distribution of the water resource. This recommendation is also important for future storage development and channel works construction.

13. REFERENCES

(1) Historical Streamflow Summary British Columbia to 1973. Water Resources Branch, Canada Department of the Environment, Ottawa, Ontario. 1974.

(2) Le Breton, E.G. Groundwater Return Flow From Irrigation at a Test Study Site in the Salmon River Valley, Shuswap Lake Basin. Water Investigations Branch, Department of Environment, Victoria, B.C. April, 1976.

(3) Le Breton, E.G. Groundwater Storage and Baseflow in the Westwold-Falkland Area, Salmon River Valley, Shuswap Lake Basin. Water Investigations Branch, Department of Environment, Victoria, B.C. June, 1976.

(4) Low Flows in British Columbia, June-September 7-Day Averages. Water Survey of Canada, Canada Department of the Environment, Vancouver, B.C. August, 1973.

(5) Low Flows in British Columbia, Annual 7-Day Averages. Water Survey of Canada, Canada Department of the Environment, Vancouver, B.C. January, 1974.

(6) Miller, R.J. and E. Schulz. Irrigation Design Manual for Farm Systems in British Columbia. Agricultural Engineering Branch, Department of Agriculture, Victoria, B.C., 1975.

(7) Mosher, V.L. and E.H. Tredcroft. Proposed Irrigation of Grandview Flats near Armstrong, B.C. Water Rights Branch, Department of Lands and Forests, Victoria, B.C. January, 1949.

(8) Obedkoff, W. Inventory of Storage and Diversion and Their Effect on Flow Records in the Okanagan River Basin. Canada-British Columbia Okanagan Basin Agreement. Water Investigations Branch, Department of Lands, Forests and Water Resources, Victoria, B.C. August, 1971.

(9) Obedkoff, W. Regionalization of Sub-Basin Hydrology. Canada-British Columbia Okanagan Basin Agreement. March, 1973. Also published as Application of the Grid Square Method for Estimating Okanagan Sub-Basin Runoff. Water Investigations Branch, Department of Lands, Forests and Water Resources, Victoria, B.C. September, 1972.

(10) Obedkoff, W. Similkameen Basin Hydrology. Water Investigations Branch, Department of Lands, Forests and Water Resources, Victoria, B.C. November, 1973.

(11) The Problem of Restoration of Salmon in the Salmon River. Canada Department of Fisheries, Vancouver, B.C. and International Pacific Salmon Fisheries Commission, New Westminster, B.C. December, 1954.

(12) Ralph, K. Temperature and Decreasing Numbers of Salmon in the Salmon River. Fish and Wildlife Branch, Department of Recreation and Travel Industry, Kamloops, B.C. January, 1976.

(13) Raudsepp, V. Salmon River Investigation. Water Rights Branch, Department of Lands and Forests, Victoria, B.C. June, 1953.

(14) Stream Improvement Handbook. Maccaferri Gabions of America, Inc., 55 W42nd St., New York, N.Y. 10036.

APPENDIX A

AREA-ELEVATION CURVES

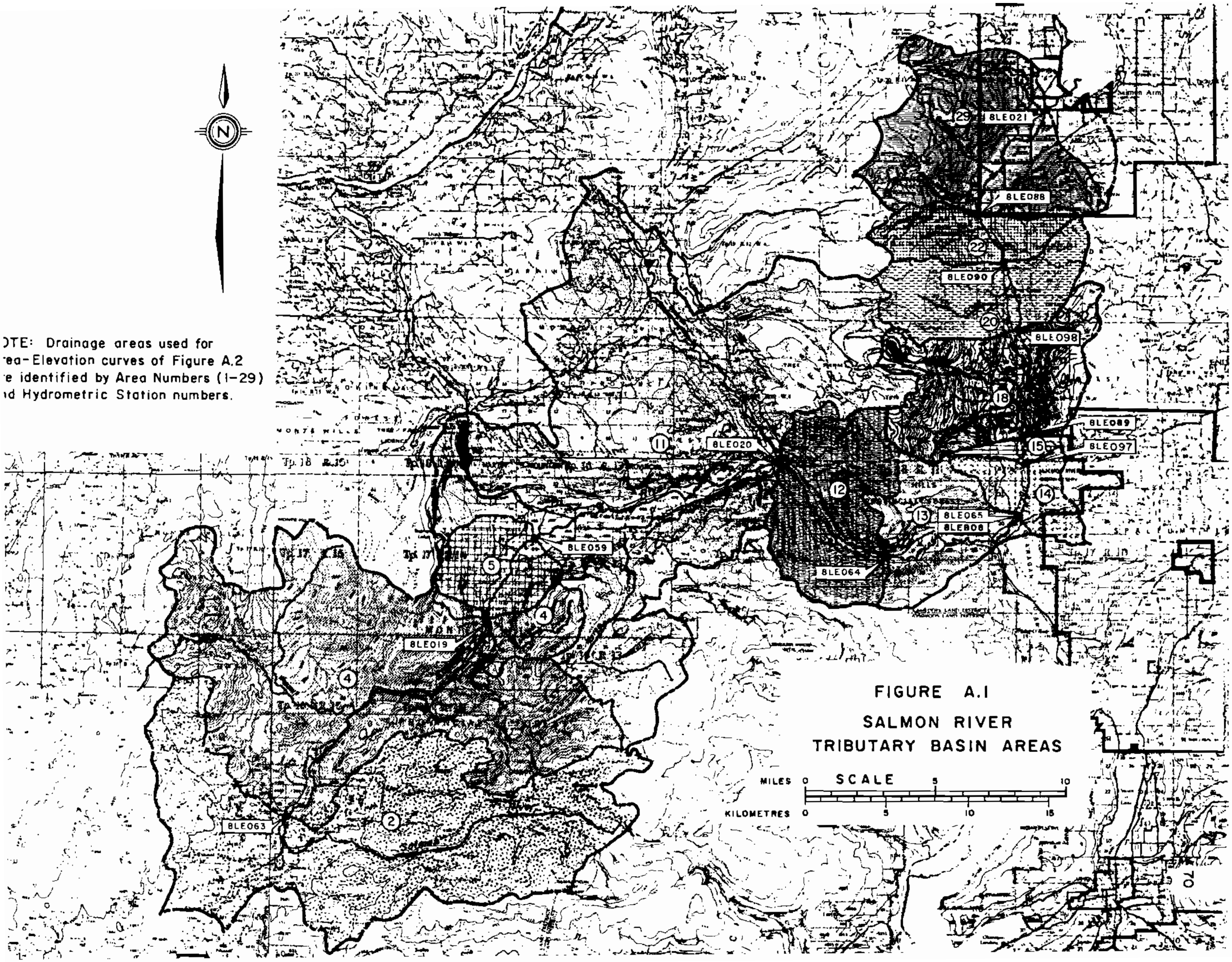


FIGURE A.1
SALMON RIVER
TRIBUTARY BASIN AREAS

OTE: Drainage areas used for
rea-Elevation curves of Figure A.2
e identified by Area Numbers (1-29)
d Hydrometric Station numbers.

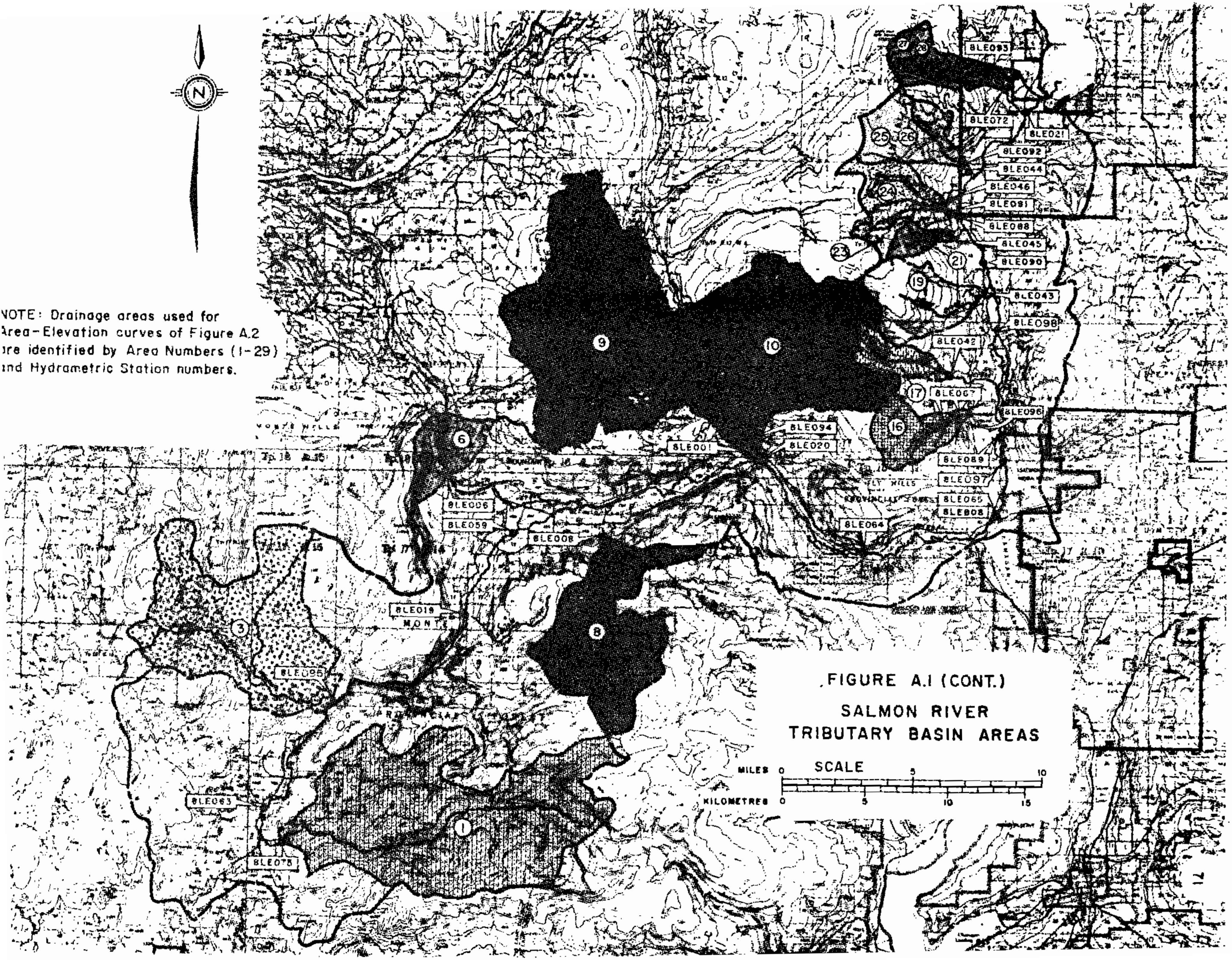
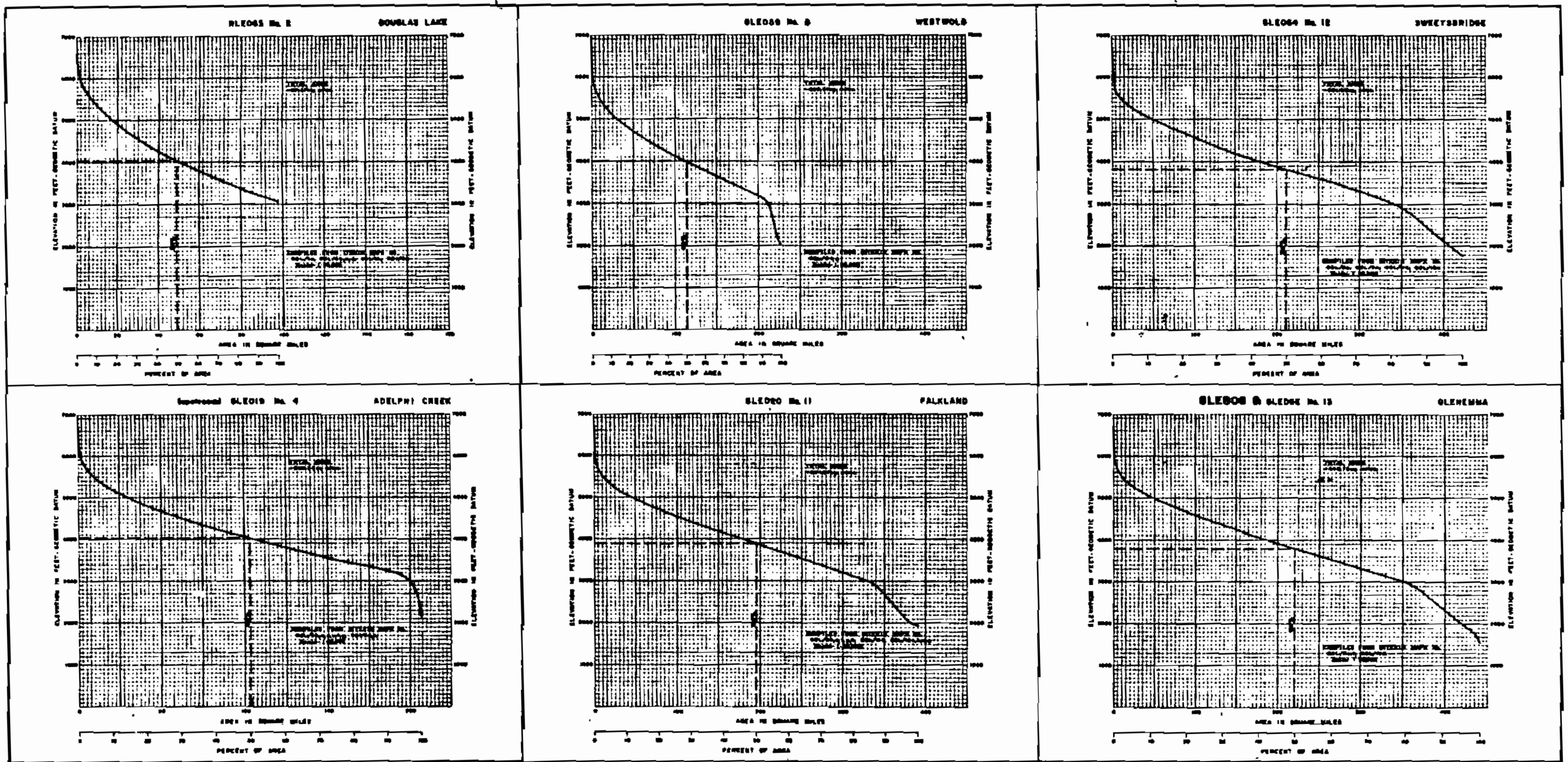


FIGURE A.1 (CONT.)

SALMON RIVER
TRIBUTARY BASIN AREAS

SCALE

NOTE: Drainage areas used for Area-Elevation curves of Figure A.2 are identified by Area Numbers (1-29) and Hydrametric Station numbers.



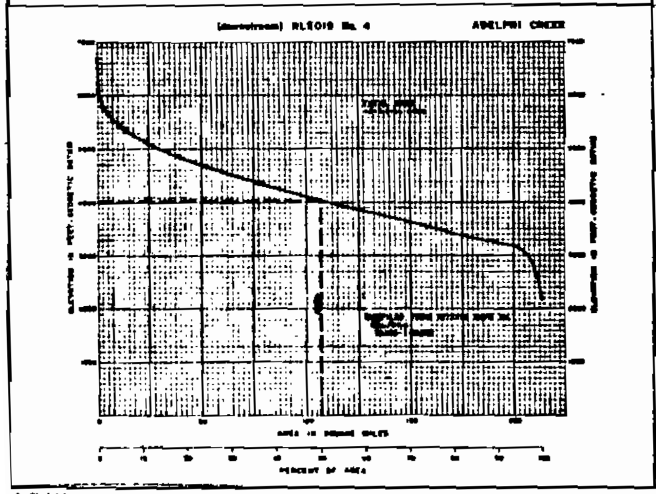


FIGURE A.2
SALMON RIVER BASIN AREA-ELEVATION CURVES

SALMON RIVER MAIN BASIN
PLAN SHOWING
AREA-ELEVATION CURVES

SEPT. 1970

456TB-5A

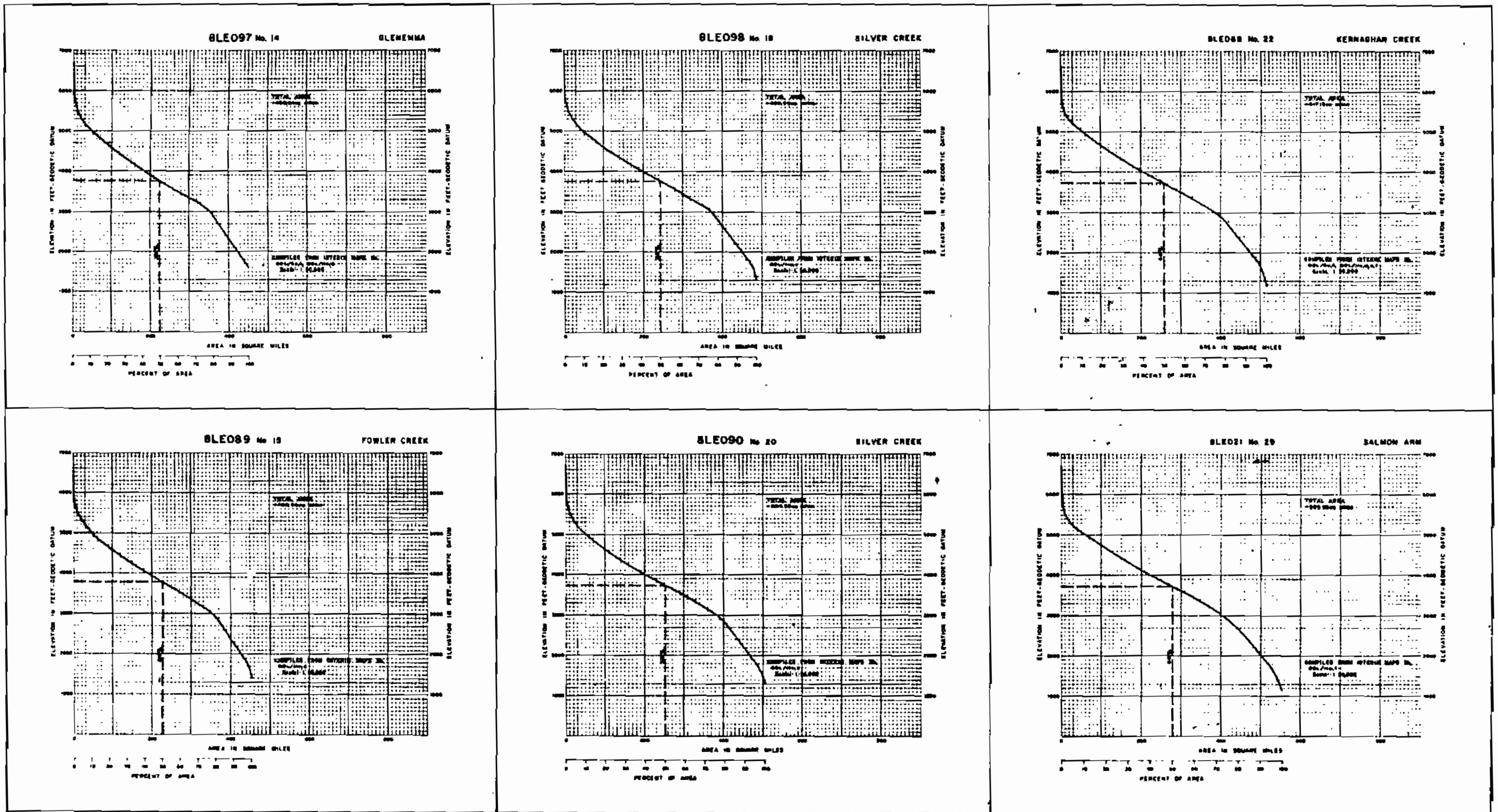


FIGURE A.2 (CONT'D.)

SALMON RIVER BASIN
AREA-ELEVATION CURVES

OKANAGAN BASIN STORAGE INVENTORY PROGRAMME
SALMON RIVER MAIN BASIN
PLAN SHOWING
AREA-ELEVATION CURVES

45678-5A

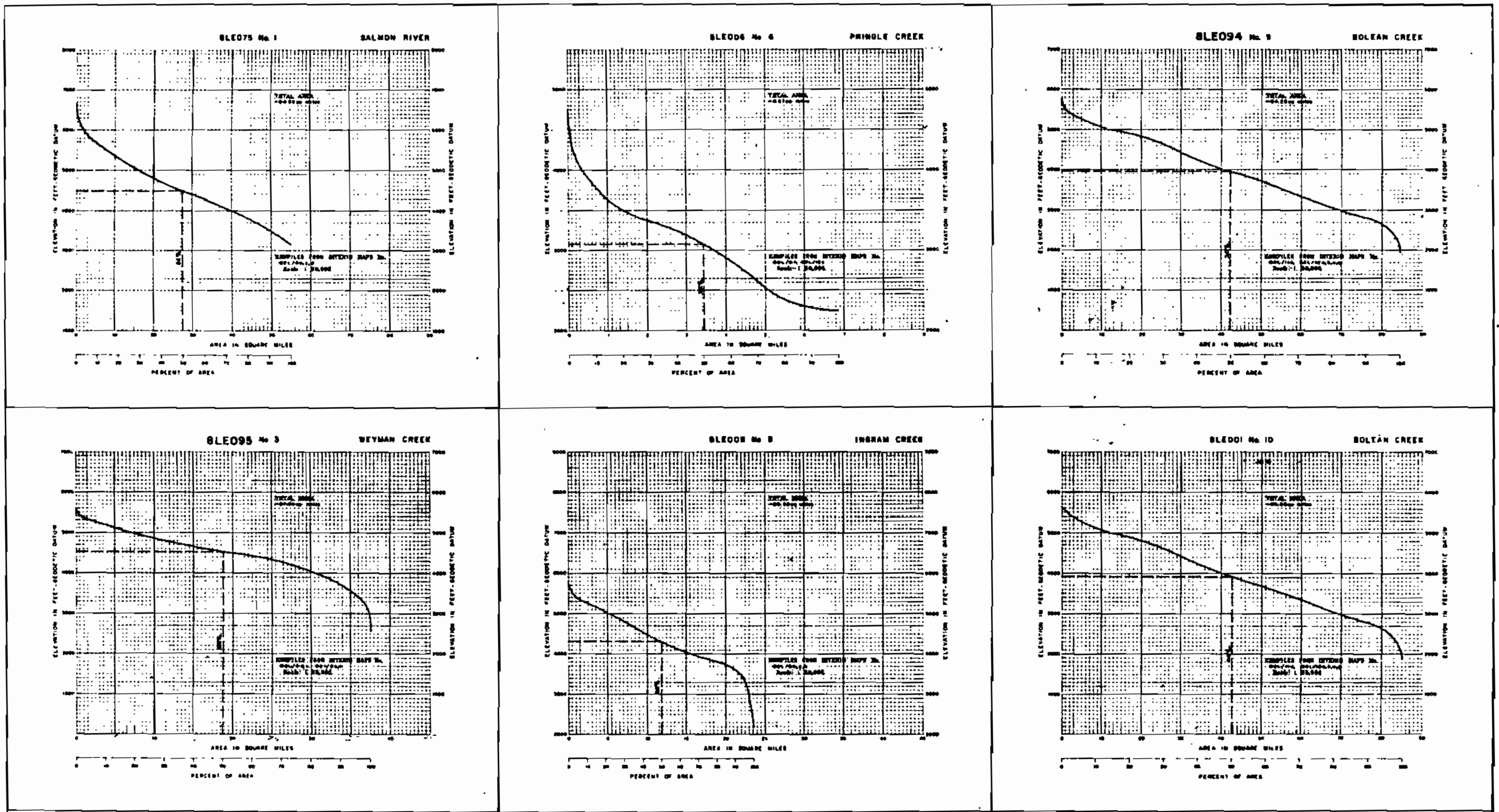


FIGURE A.2 (CONT'D.)

SALMON RIVER BASIN
AREA-ELEVATION CURVES

OKANAGAN BASIN STORAGE INVENTORY PROGRAMME

SALMON RIVER SUB BASIN

PLAN SHOWING

AREA-ELEVATION CURVES

OCT. 1975

4567B-5A

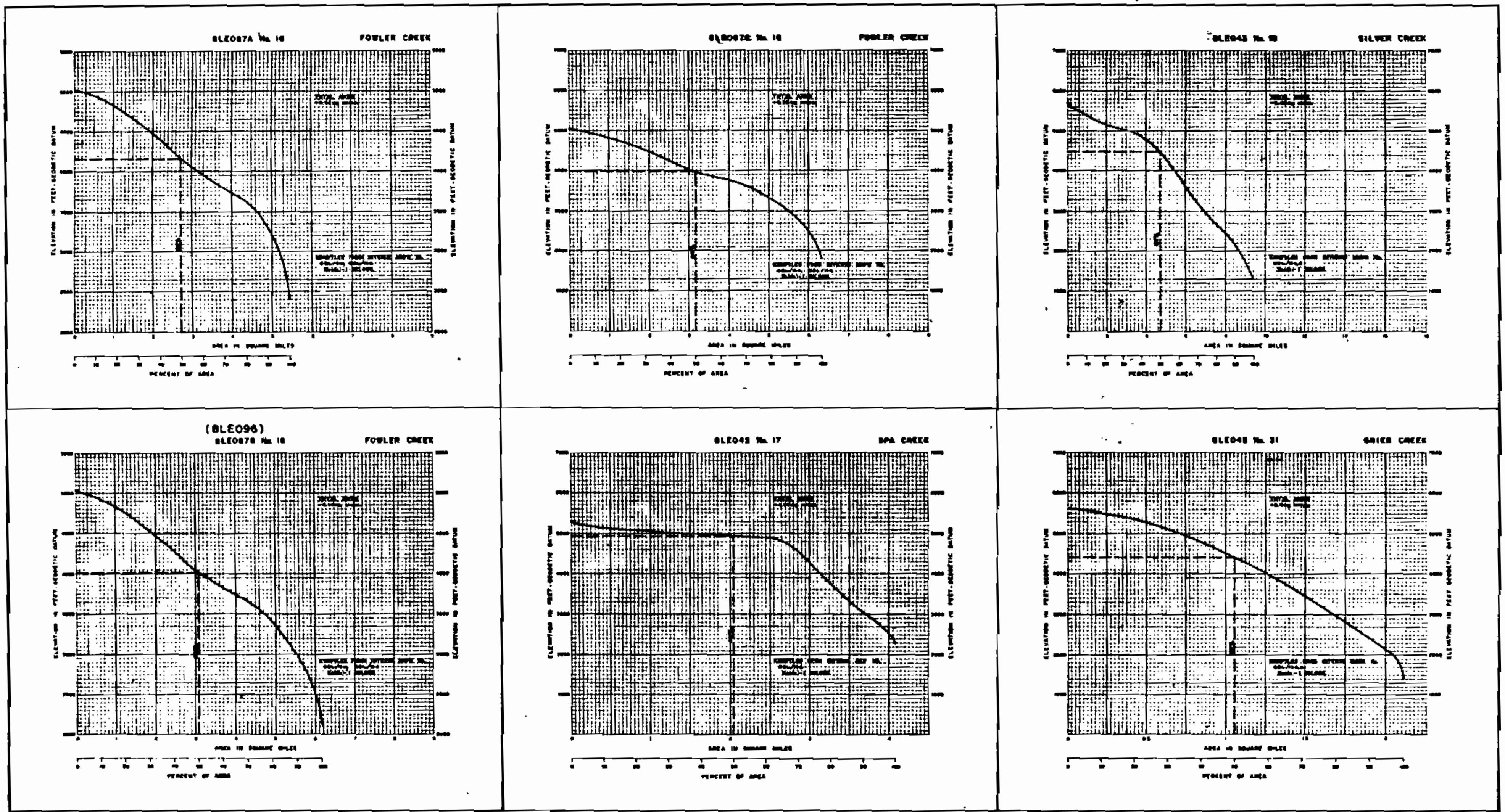


FIGURE A.2 (CONT'D.)

SALMON RIVER BASIN
AREA-ELEVATION CURVES

SALMON RIVER SUB BASIN
PLAN SHOWING
AREA-ELEVATION CURVES
45678-BA

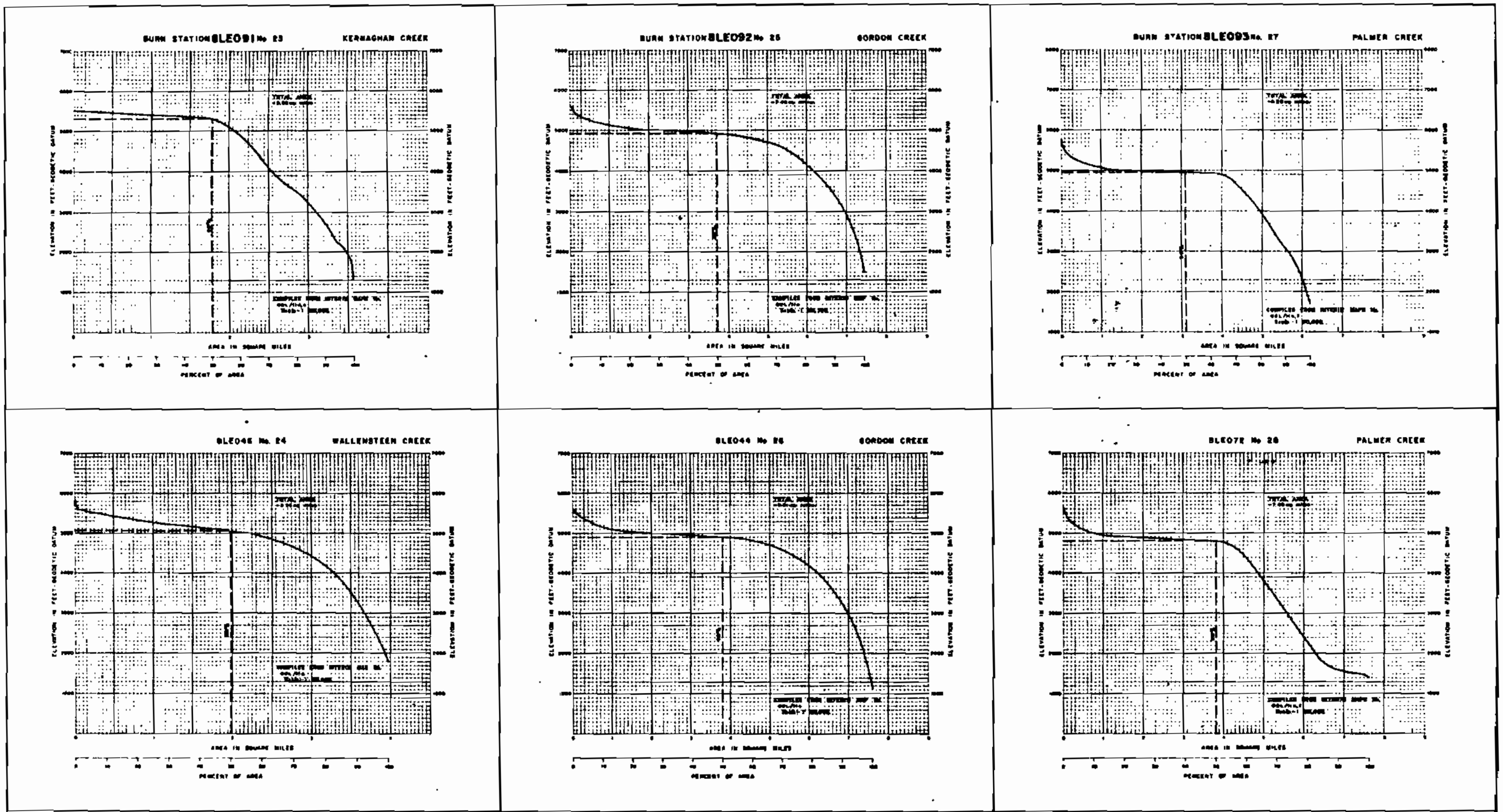


FIGURE A.2 (CONT'D.)

SALMON RIVER BASIN
AREA-ELEVATION CURVES

OKANAGAN BASIN STORAGE INVENTORY PROGRAMME
SALMON RIVER SUB BASIN
PLAN SHOWING
AREA-ELEVATION CURVES

OCT., 1975

45678-5A

APPENDIX B

HYDROLOGIC DATA

TABLE 8.1 SALMON RIVER CHANNEL SURVEY

Regular and Miscellaneous Discharge Measurements

MEASUREMENT SITE	SALMON RIVER LOCATION Listed in Upstream to Downstream Order	SEPTEMBER-OCTOBER, 1974			SEPTEMBER, 1975			REMARKS
		Date	Gauge Height (ft.)	Discharge (cfs)	Date	Gauge Height (ft.)	Discharge (cfs)	
M1	2.4 mi. ab. Salmon Lk. ab. br.	24	-	3.3	10	-	4.7	
8LE075	ab. Salmon Lk.	24-27		3.4	9-11	3.17	5.0	WSC
M2	Control outlet of Salmon Lk.	24	-	0.3	10	-	2E	
M2a	bl. confl. Salmon R. and Salmon Lk. outlet	-	-	-	10	-	2.3	
M3	400 ft. d/s of falls	25	-	2.0	10	-	5.0	3.5 mi. bl. Salmon Lk.
M4	0.8 mi. u/s of Keyman Cr.	25	-	2.4	10	-	5.8	4 ft. u/s upper br.
M4a		-	-	-	10	-	5.8	35 ft. u/s lower br.
8LE095	(Keyman Cr. nr. mouth)	25	-0.05	(1.5E)	10	-0.15	(1.0)	
M5	1500 ft. d/s of Keyman Cr.	25	-	3.5	10	-	6.2	
M6	2.8 mi. d/s of Keyman Cr.	-	-	not meas.	10	-	4.8	900 ft. d/s log barn
8LE019	ab. Adelphi Cr.	25	4.40	2.4	10	3.69	5.5	
M7	u/s of Talbot Div.	26	-	0.8	9	-	3.5	1.4 mi. bl. Adelphi Cr.
				0.0			0.0	dry section of river
M8	u/s of Westwold	26	-	0.07	9	-	0.6	100 ft. d/s pumphouse, 2.6 mi. bl. Adelphi Cr.
				0.0			0.0	dry section of river
M9	200 ft. u/s of Pringle Cr.	26	-	1.6	9	-	1.8	
8LE006	(Pringle Cr.)	-	-	-	11	-	(4.4)	20 ft. u/s gauge
M10	75 ft. d/s of Pringle Cr.	26	-	6.4	9	-	6.5	
M11	0.5 mi. d/s of Pringle Cr.	26	-	18.5	9	-	23.0	60 ft. u/s corral br.
8LE008	(Ingram Cr.)	9	1.10	(1.5)	11	1.02	(1.3)	dry mouth
M14, F7	1½ mi. u/s of Falkland	27	-	25.0	9	1.51	32.1	
M13	u/s of Bolean Cr.	27	-	26.7	9	-	33.3	10 ft. u/s confl.
8LE094	(Bolean Cr. nr. mouth)	27	0.00	(3.[illegible])	11	0.17	(7.6)	300 ft. u/s gauge
M12	(Bolean Cr. at mouth)	27	-	(2.[illegible])	9	-	(5.2)	20 ft. d/s railway br.
M15	d/s of Bolean Cr.	30	-	31.9	9	-	39.9	10 ft. d/s confl.
8LE020	at Falkland	26	1.67	27.2	9-11	1.74	41.2	WSC
F6	2 mi. d/s of Falkland bl. br.	1	-	31.2	9	1.09	39.9	
8LE064, F5	at Sweetsbridge	25	1.05	29.4	9 11	0.94 0.94	43.0	100 ft. u/s br.
8LE808	at Glenemma	25	1.05	28.2	9 11	1.46 1.44	43.7	20 ft. d/s br.
8LE097	nr. Glenemma	26	0.67	29.4	9 11	0.88 0.86	43.8	30 ft. d/s br.
8LE089, F4	ab. Fowler Cr.	26	0.64	24.8	9 11	0.90 0.89	43.2	
8LE096	(Fowler Cr. nr. mouth)	7	0.89	(1.2)	11	0.86	(1.9)	
8LE098	1½ mi. ab. Silver Cr.	26	1.32	32.8	9 11	15.80 15.82	49.9	100 ft. u/s br.
8LE090, F3	1 mi. bl. Silver Cr.	26	1.64	35.5	9,10 11	1.70 1.71	57.7	200 ft. d/s hwy. br.
8LE088	1/8 mi. u/s of Kernaghan	26		40.0	9,10 11	3.19 3.17	54.2 51.6	WSC Sept. 9: 3.24ft., E.G.L. Sept. 10: 3.22ft., W.O.
8LE091	(Kernaghan Cr. ab. div.)	27	0.06	(1.0)	9		(1.3)	
8LE092	(Gordon Cr. ab. div.)	27	0.03	(0.5)	9		(1.9)	
8LE044	(Gordon Cr. nr. Salmon Arm)	27		(0.05)	9	1.55	(0.5)	WSC
F2	100 ft. u/s of 50th Ave. SW br. (1974)	27	-	43.6	10 9; 11	 14.33; 14.36	65.1	200 ft. u/s of 50th Ave. br. (1975)
F1	300 ft. u/s of br.	1		49.9				
8LE093	(Palmer Cr. ab. div.)	27	0.06	(1.6)			(2.6)	
8LE072	(Palmer Cr. nr. Salmon Arm)	26		(2.3)	9	1.29	(2.0)	WSC
8LE021	nr. Salmon Arm	26		47.9	9	1.65	74.6	WSC
F1					11	1.63	66.6	50 ft. d/s hwy. br.

Abbreviations:

E, estimated	R., River
ft., feet	Lk., Lake
mi., miles	confl., confluence
nr., near	div., diversions
ab., above	hwy., highway
bl., below	br., bridge
u/s, upstream	WSC, Water Survey of Canada
d/s, downstream	( ), tributary measurement
Cr., Creek	

Miscelleneous Measurement Site Reference System:

Adjustment of miscellaneous measurements to one standard measurement date: M8 to M11 defines starting date since these sites are remote from established hydrometric stations and this river reach is independent in the total river flow regime since it is apparently fed from a groundwater aquifer system.

M1 to M4	reference to 8LE075
M5 to M7	reference to 8LE019
M12 to M15	reference to 8LE020
F1, F2	reference to 8LE021
F3	reference to 8LE090
F4	reference to 8LE089
F5	reference to 8LE064
F6, F7	reference to 8LE020

TABLE B.2 SALMON RIVER BASIN CHARACTERISTICS AND RUNOFF

PLOT	HYDROMETRIC STATION		DRAINAGE AREA (sq.mi.)					MEDIAN BASIN ELEVATION (ft.)					MEASURED MEAN ANNUAL RUNOFF (adjusted to 1960-1969)				WATER BALANCE ANNUAL RUNOFF (October, 1974-November, 1975)			
NO.	Name	Number	Total	>3500'	>3000'	>2000'	>1500'	Total	>3500'	>3000'	>2000'	>1500'	cfs	sq.mi.in./yr.	in.> 3500'	in.> 2000'	in.> 3000'	in.> 1500'	sq.mi.in./yr.	cfs
1	Salmon R. ab. Salmon Lk.	8LE075	55	49.6	55			4480	4575	4480			27.5	373.6	7.5		6.7		368.5	27.1
2	Salmon R. nr. Douglas Lk.	8LE063	97.5	74				4050	4330				27.5	373.6	5.0					
3	Weyman Cr. nr. the Mouth	8LE095	37.6	35.5	37.3			4540	4550	4540							6.9		257.4	16.9
4	Salmon R. ab. Adelphi Cr.	8LE019	206.5	157.5	200			4020	4300	4060			57.2	777.0	4.9		4.9		980.0	72.1
5	Salmon R. nr. Westwold	8LE059	226.9	166				4000	4300				62.0	842.2	5.1					
6	Pringle Cr. nr. Westwold*	8LE006	6.9	1.4				3080	3790				5.9	80.1	57.2*					
7	Ingram Cr. nr. the Mouth	8LE008	23.6	21.9	23			4300	4390	4340							6.0		138.0	10.2
8	Ingram Cr. nr. Mouth	8LE008	23.6	21.9				4300	4390				8.7	118.2	5.4					
9	Bolean Cr. nr. the Mouth	8LE094	84.3	56.1	69.6	77†	84.3	3960	4540	4220	4090†	3960					7.1		542.4	40.1
10	Bolean Cr. at Falkland	8LE001	85.1	55.4	70.2†	84.9		3920	4530	4225†	3920		35.6	483.6	8.7					
11	Salmon R. at Falkland	8LE020	391.9	255	330	383	391.9	3890	4340	4080	3920	3890	95.2	1293.2	5.1		5.0		1650.0	121.5
12A	12-11		29.6	12.5		24	29.6		3910		2730	2750		324.7		13.5		5.4	159.8	11.5
12	Salmon R. nr. Falkland	8LE064	421.5	267.5		407	421.5	3810	4320		3850	3810	119.1	1617.9	6.0					133.3
13A	13-11					37	48.8				3240	2990						6.3	307.4	22.6
13	Salmon R. at Glenemma	8LE065	440.7	270		420	440.7	3800	4330		3860	3790	118.7	1612.4	6.0					144.1
14A	14-11					41	58.1				3200	2880						5.9	342.8	25.2
14	Salmon R. nr. Glenemma	8LE097	450	270		424	450	3770	4330		3850	3760								146.7
15A	15-11					44	60.8				3240	3070						6.7	407.4	30.0
15	Salmon R. ab. Fowler Cr.	8LE089	452.7	274		427	452.7	3780	4320		3850	3780								151.5
16	Fowler Cr. at 2100-ft. contour	8LE096	6.1			6.1	6.1	4020			4100	4030	3.4	46.2		7.6		11.2	68.3	5.0
17	Spa Cr. ab. Cowersmith Div.	8LE042	4.1			4.1		4920			4920		3.9	53.0		12.9				
18A	18-11					67	90.1				3450	3190						7.1	639.7	47.1
18	Salmon R. ab. Silver Cr.	8LE098	483.9	288		450	482	3750	4310		3850	3760								165.6
19	Silver Cr. nr. Salmon Arm	8LE043	9.4			8.7		4500			4650		8.0	108.7		12.5				
20A	20-11					83	108.1				3470	3200						7.2	778.3	57.3
20	Salmon R. bl. Silver Cr.	8LE090	504.6	300		466	500	3730	4300		3840	3740								178.8
21	Wilcox Cr. nr. Salmon Arm	8LE045	2.1			2		4410			4475		2.8	38.0		19.0				
22A	22-11					93	116.1				3460	3280						7.5	870.8	64.1
22	Salmon R. ab. Kernaghan Cr.	8LE088	517.1	302		476	508	3730	4330		3830	3750								185.6
23	Kernaghan Cr. ab. Div.	8LE091	3.6			3.5	3.6	5300			5320	5300						18.5	66.6	4.9
24	Wallensteen Cr. nr. Salmon Arm	8LE046	4			3.9		5060			5060		3.7	50.3		12.9				
25	Gordon Cr. ab. Div.	8LE092	7.5			7.3	7.5	4900			4910	4900						16.1	120.8	8.9
26	Gordon Cr. nr. Salmon Arm	8LE044	7.6			7.4	7.5	4880			4890	4880	10.6	144.0		19.5				
27	Palmer Cr. ab. Div.	8LE093	6.2			6.1	6.2	4950			4950	4950						16.5	102.3	7.5
28	Palmer Cr. nr. Salmon Arm	8LE072	7.6			6.4	7.6	4900			4910	4900	7.7	104.6		16.3		16.1	122.4	9.0
29A	29-11		164.7	69		119	148.1		4390		3670	3420		876.2		7.4		8.2	1214.4	89.4
29	Salmon R. nr. Salmon Arm	8LE021	556.6	324		502	540	3720	4350		3860	3760	159.7	2169.4		4.3				210.9

*Diversion from Monte Cr.
†Bolean Cr. area is covered in approximately equal portions by both hydrologic zones.

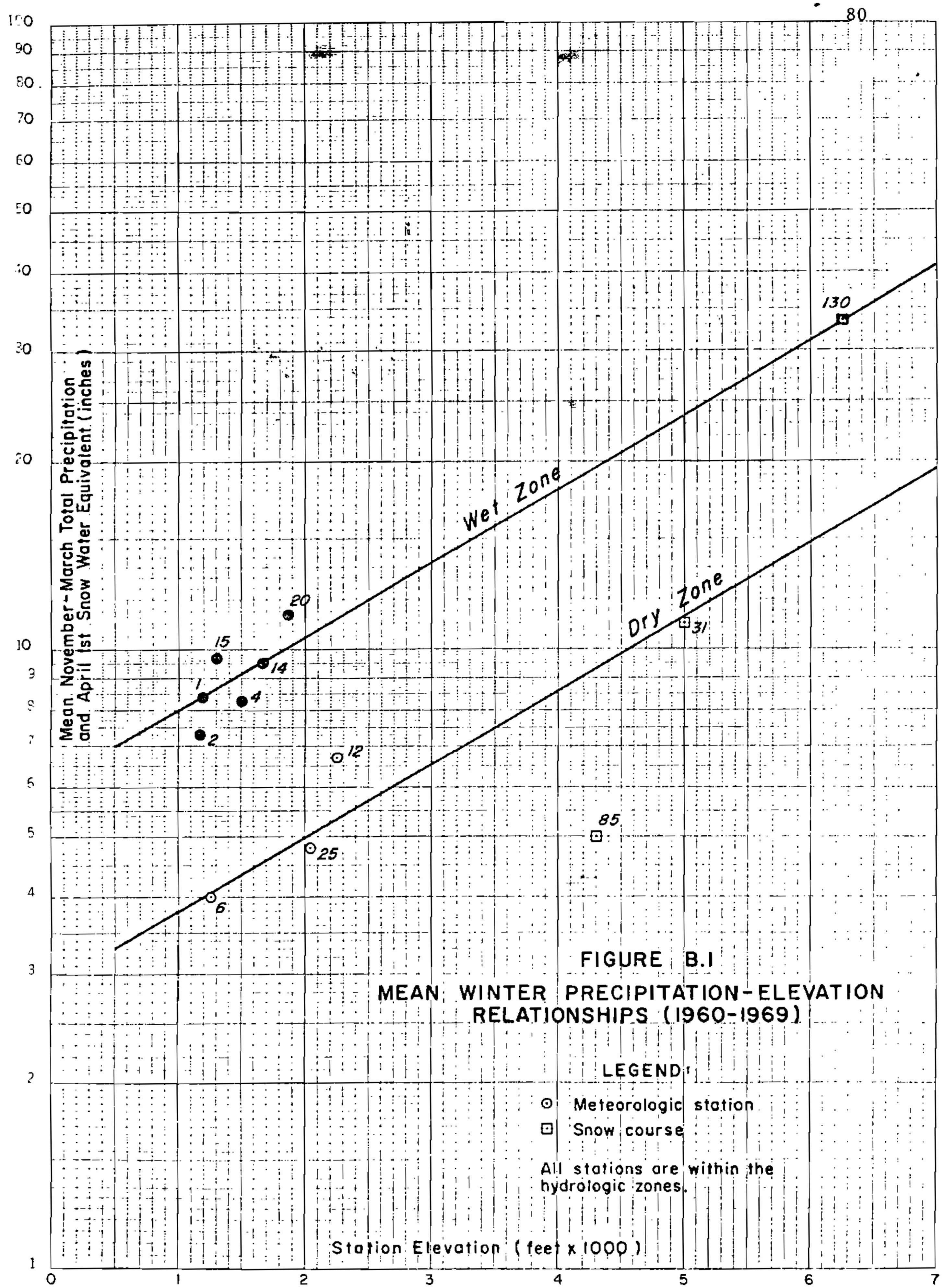


FIGURE B.1
MEAN WINTER PRECIPITATION-ELEVATION RELATIONSHIPS (1960-1969)

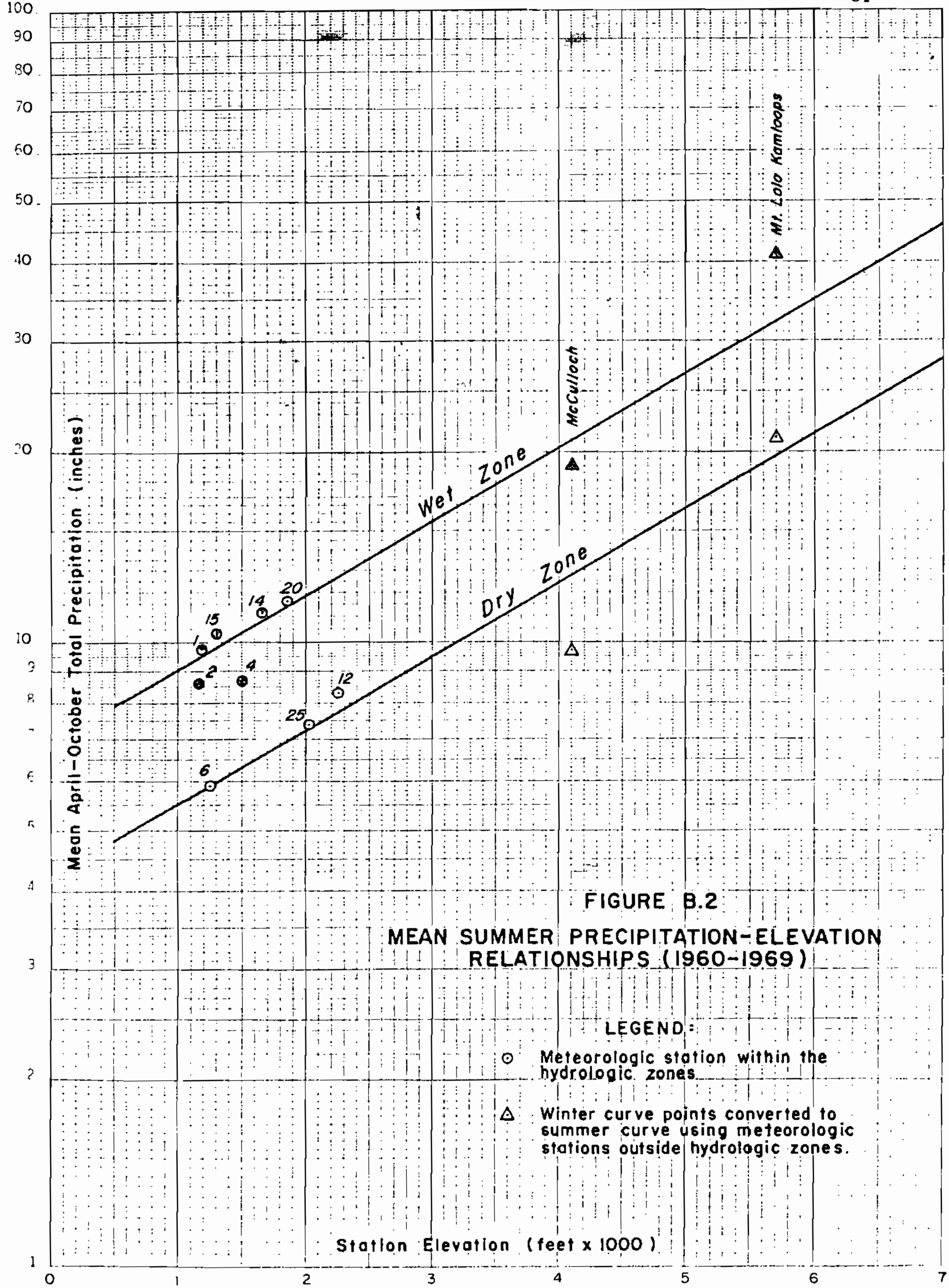


FIGURE B.2

MEAN SUMMER PRECIPITATION-ELEVATION RELATIONSHIPS (1960-1969)

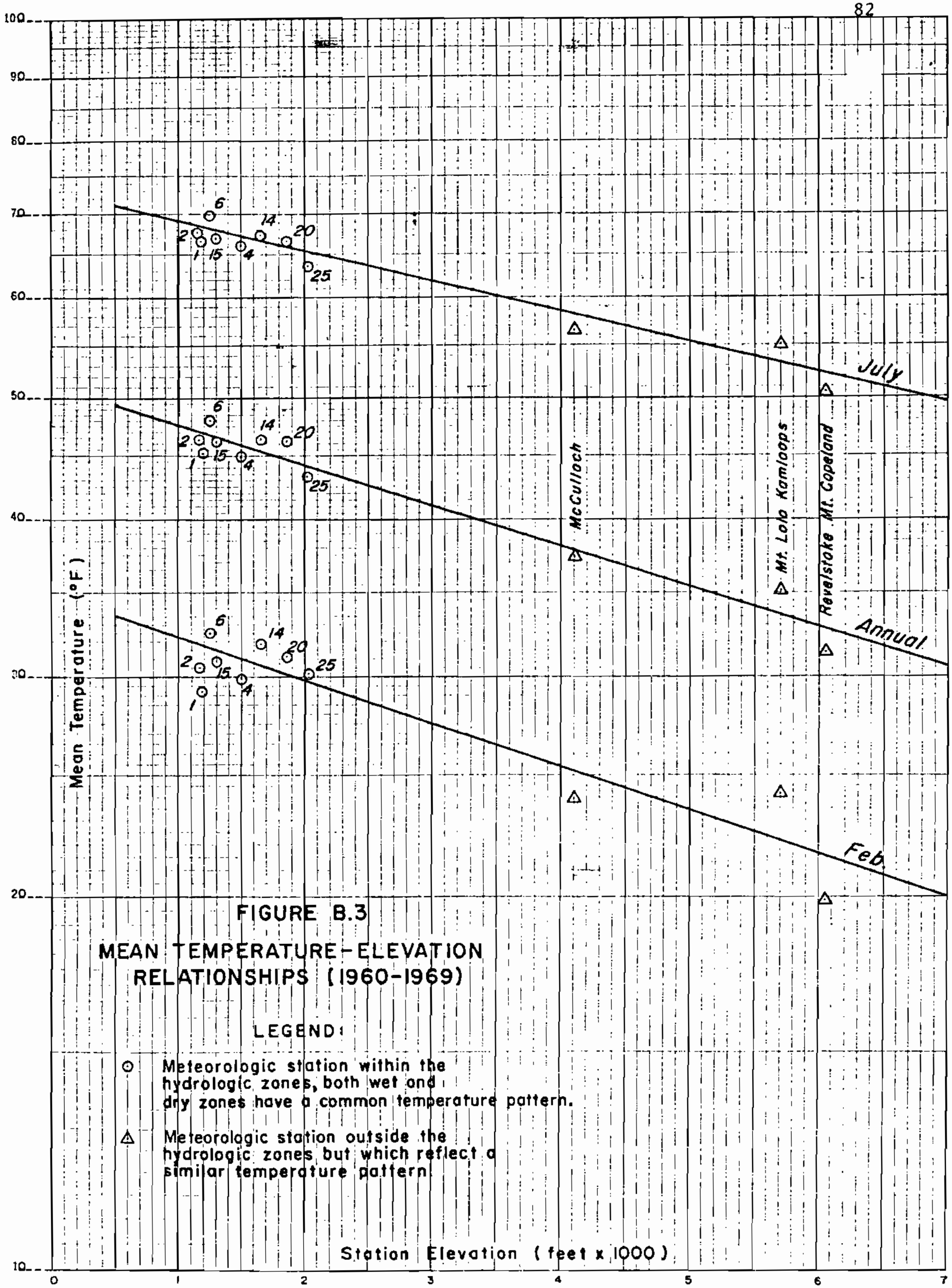


FIGURE B.3

MEAN TEMPERATURE-ELEVATION RELATIONSHIPS (1960-1969)

LEGEND:

⊙ Meteorologic station within the hydrologic zones, both wet and dry zones have a common temperature pattern.

△ Meteorologic station outside the hydrologic zones but which reflect a similar temperature pattern.

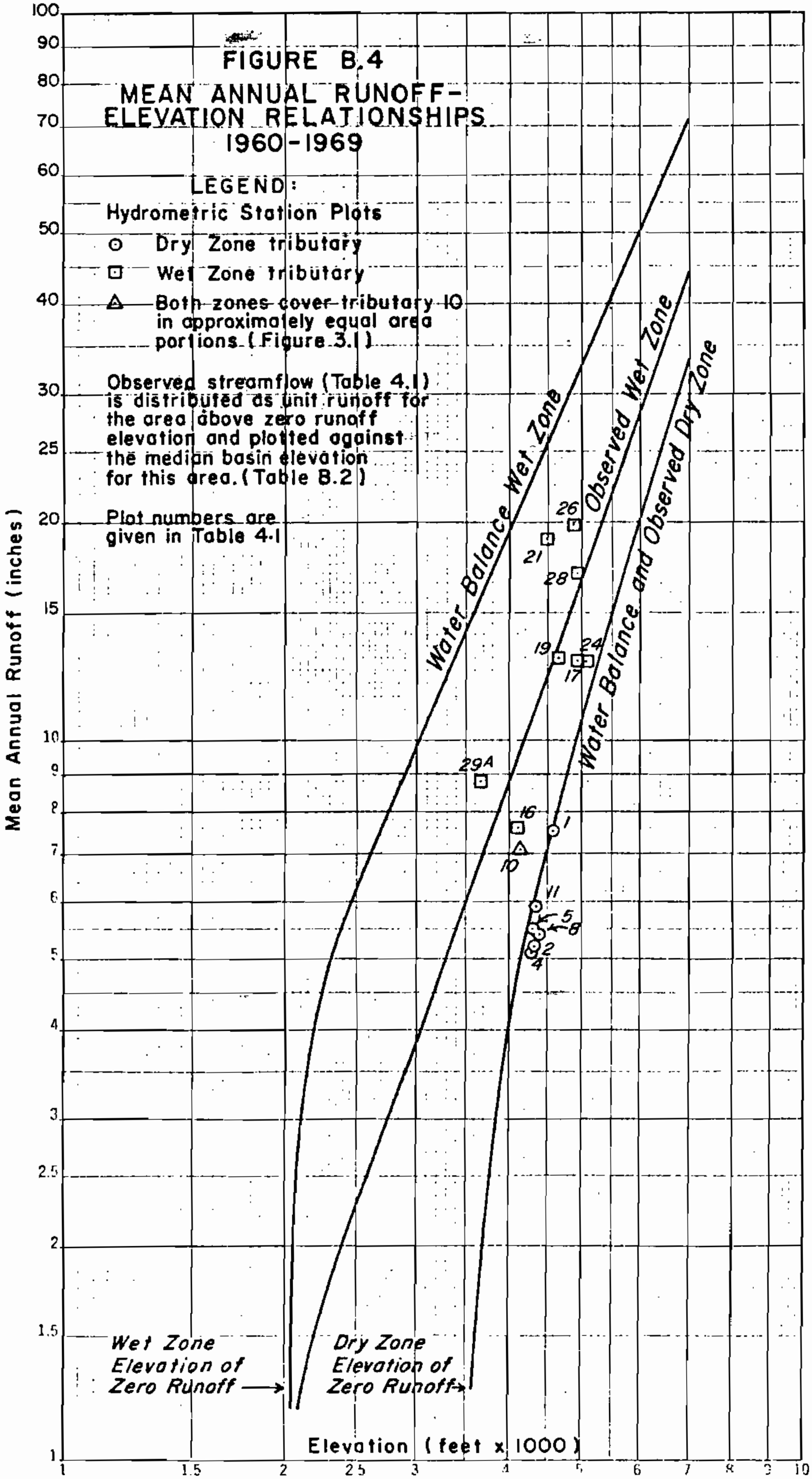


FIGURE B.4
MEAN ANNUAL RUNOFF-ELEVATION RELATIONSHIPS
1960-1969
LEGEND:
Hydrometric Station Plots
Dry Zone tributary
Wet Zone tributary
Both zones cover tributary 10 in approximately equal area portions (Figure 3.1)
Observed streamflow (Table 4.1) is distributed as unit runoff for the area above zero runoff elevation and plotted against the median basin elevation for this area. (Table B.2)
Plot numbers are given in Table 4.1
Water Balance Wet Zone
Observed Wet Zone
Water Balance and Observed Dry Zone
Wet Zone Elevation of Zero Runoff
Dry Zone Elevation of Zero Runoff
Mean Annual Runoff (inches)
Elevation (feet x 1000)
26
21
28
19
24
17
29A
16
1
10
11
5
8
2
4
100
90
80
70
60
50
40
30
25
20
15
10
9
8
7
6
5
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5
6
7
8
9
10

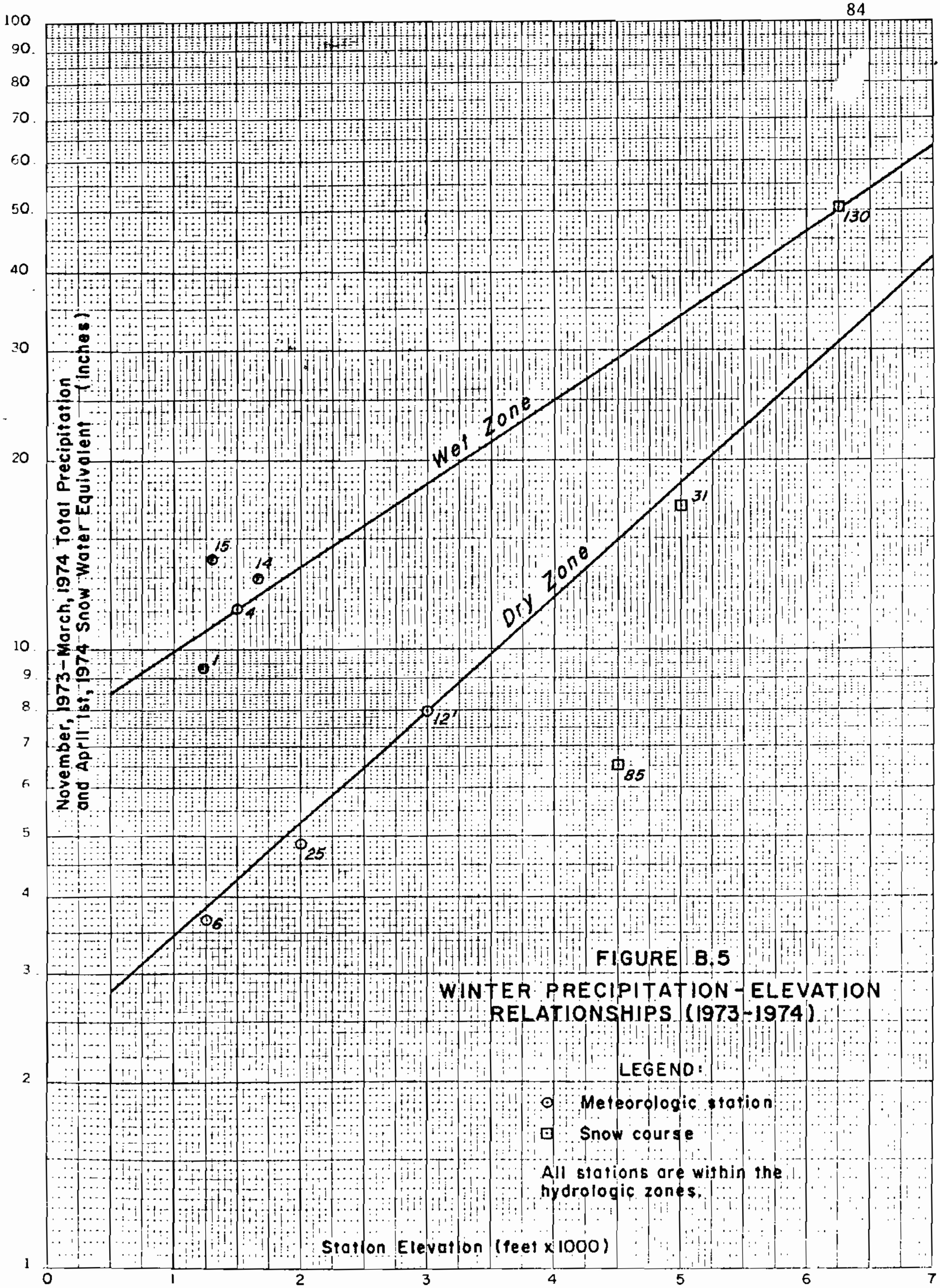

FIGURE B.5
WINTER PRECIPITATION-ELEVATION RELATIONSHIPS (1973-1974)

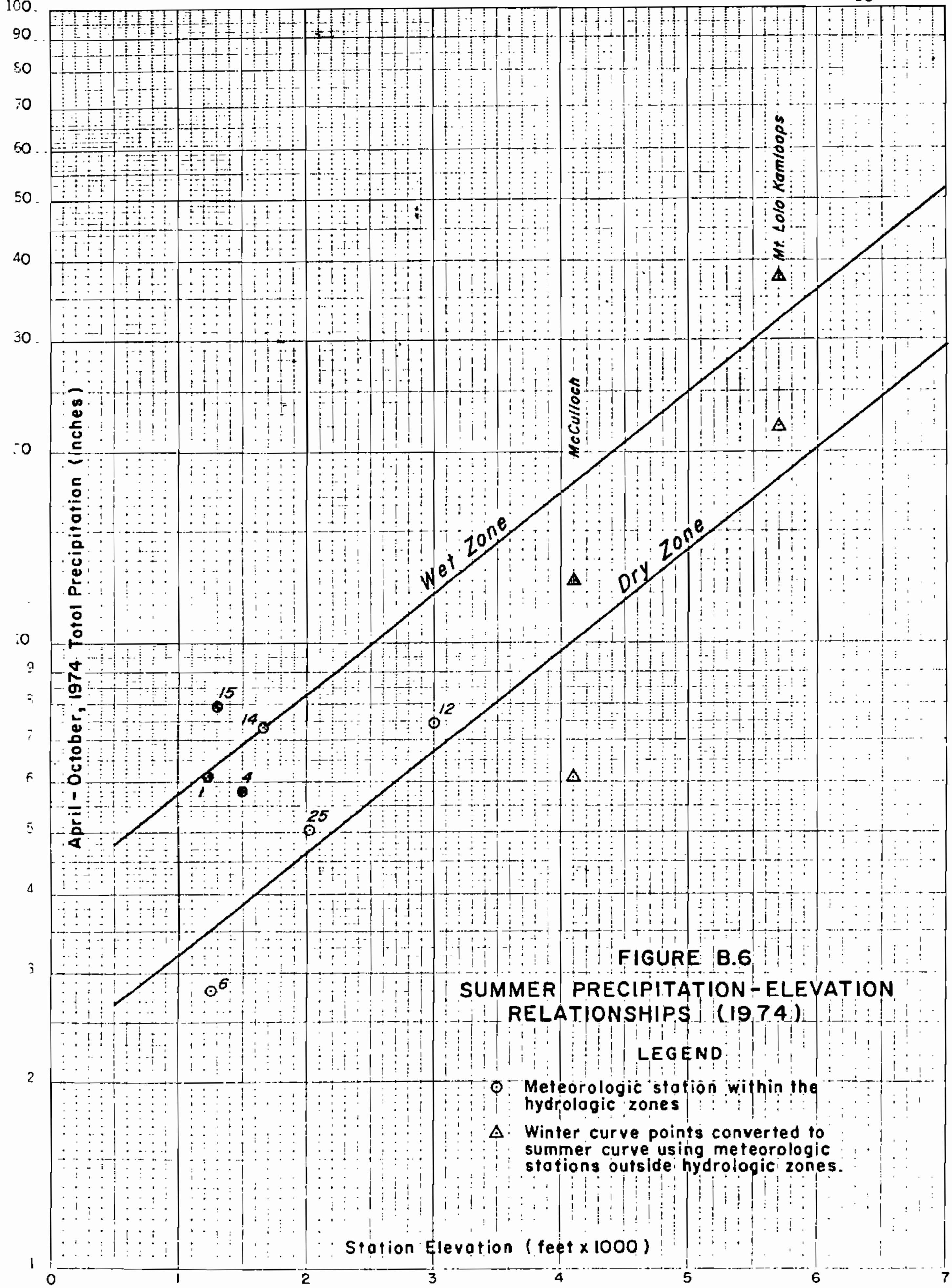

FIGURE B.6
SUMMER PRECIPITATION-ELEVATION RELATIONSHIPS (1974)

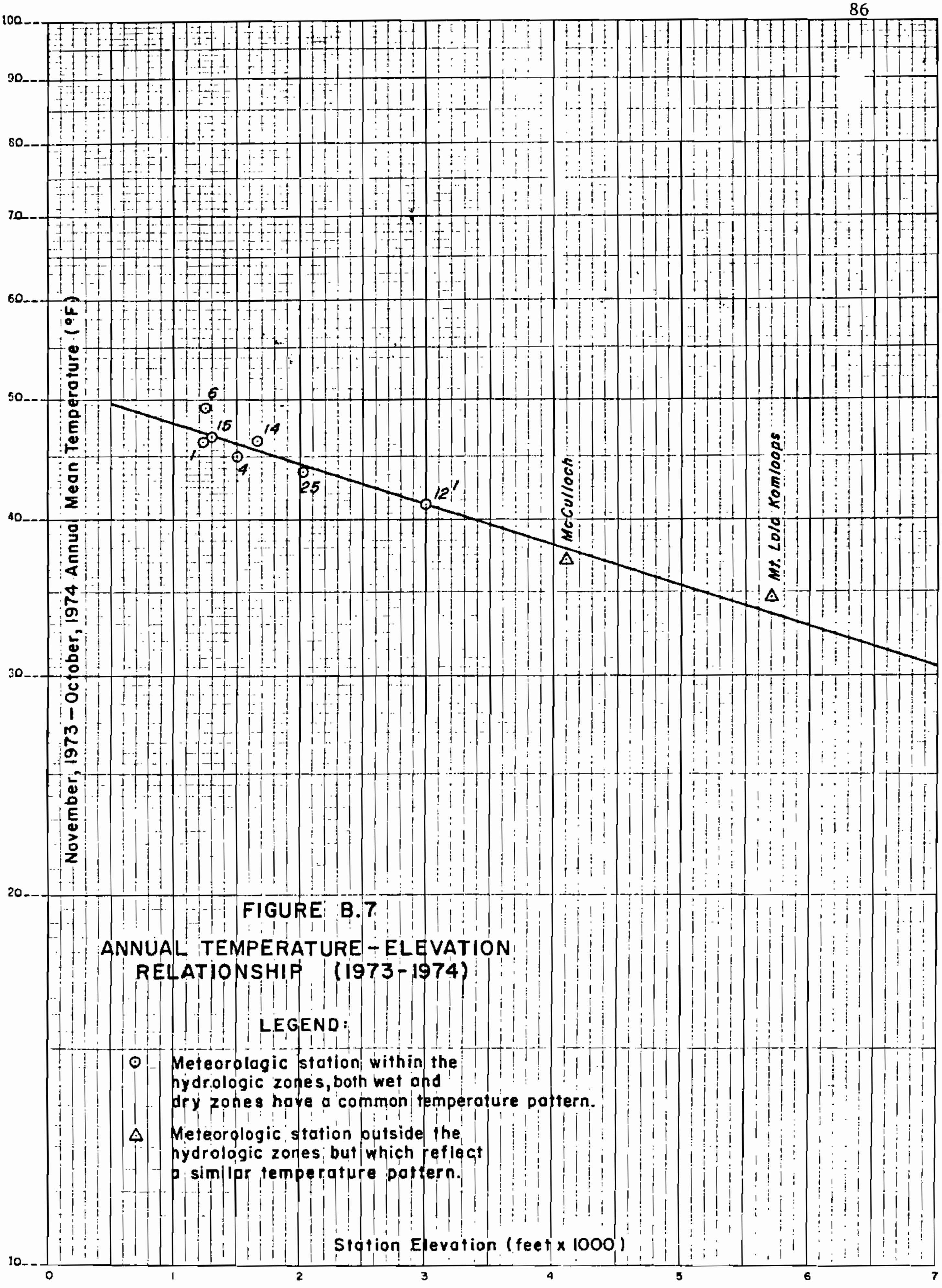

FIGURE B.7

ANNUAL TEMPERATURE – ELEVATION RELATIONSHIP (1973 - 1974)

LEGEND:

⊙ Meteorologic station within the hydrologic zones, both wet and dry zones have a common temperature pattern.

△ Meteorologic station outside the hydrologic zones but which reflect a similar temperature pattern.

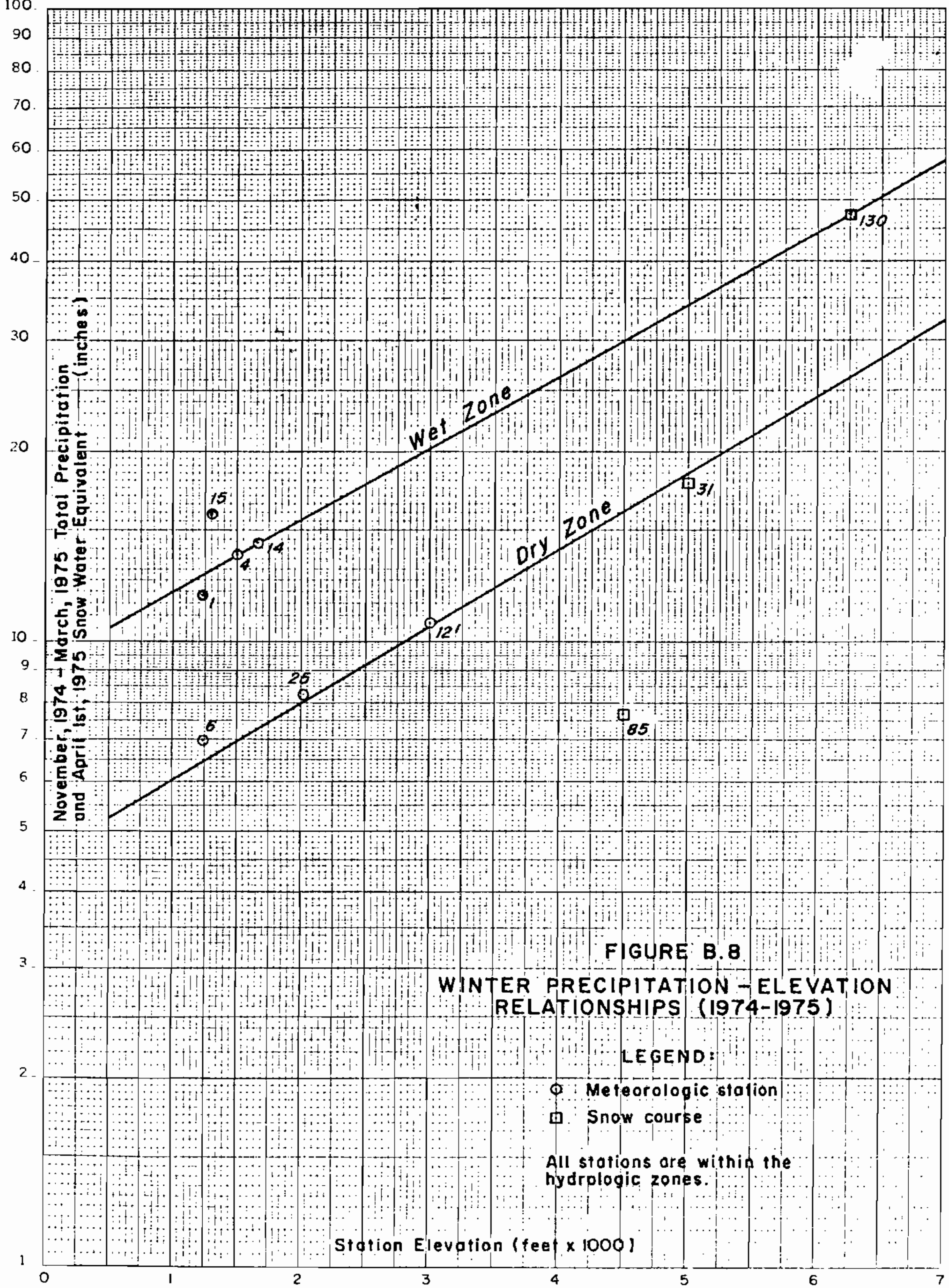

FIGURE B.8

WINTER PRECIPITATION - ELEVATION RELATIONSHIPS (1974-1975)

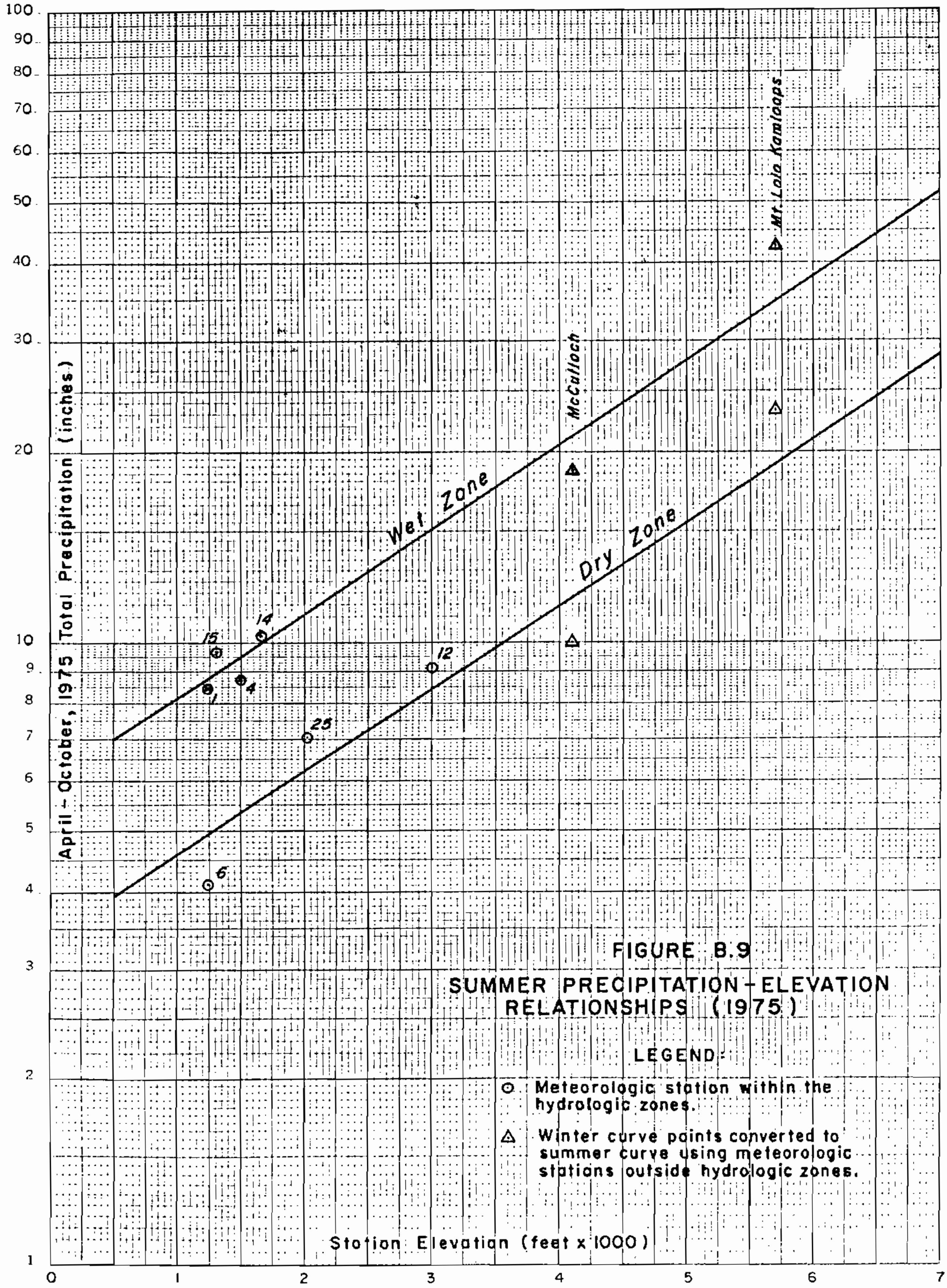

FIGURE B.9
SUMMER PRECIPITATION - ELEVATION RELATIONSHIPS (1975)

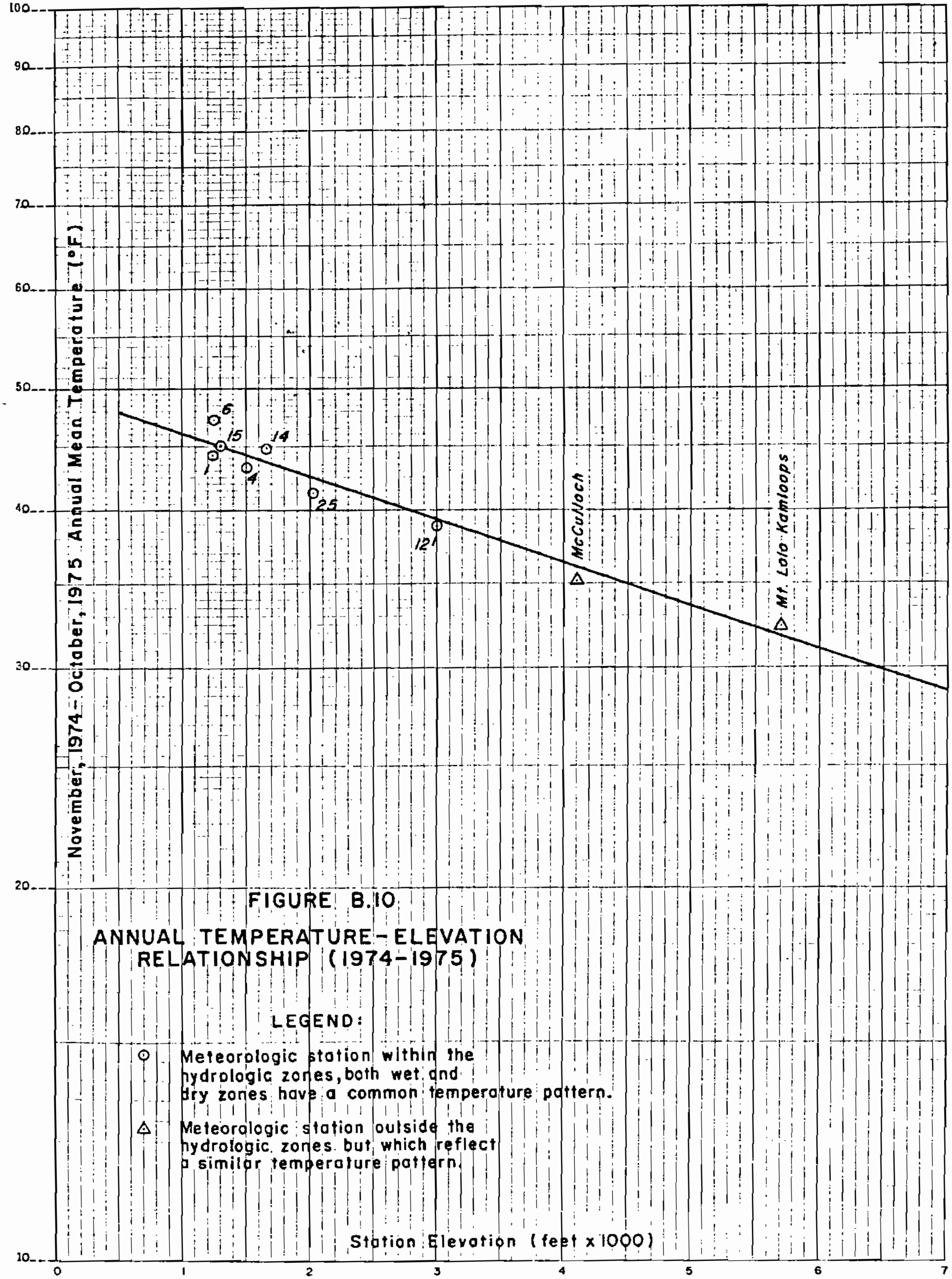

FIGURE B.10

ANNUAL TEMPERATURE - ELEVATION RELATIONSHIP (1974-1975)

LEGEND:

⊙ Meteorologic station within the hydrologic zones, both wet and dry zones have a common temperature pattern.

△ Meteorologic station outside the hydrologic zones but which reflect a similar temperature pattern.

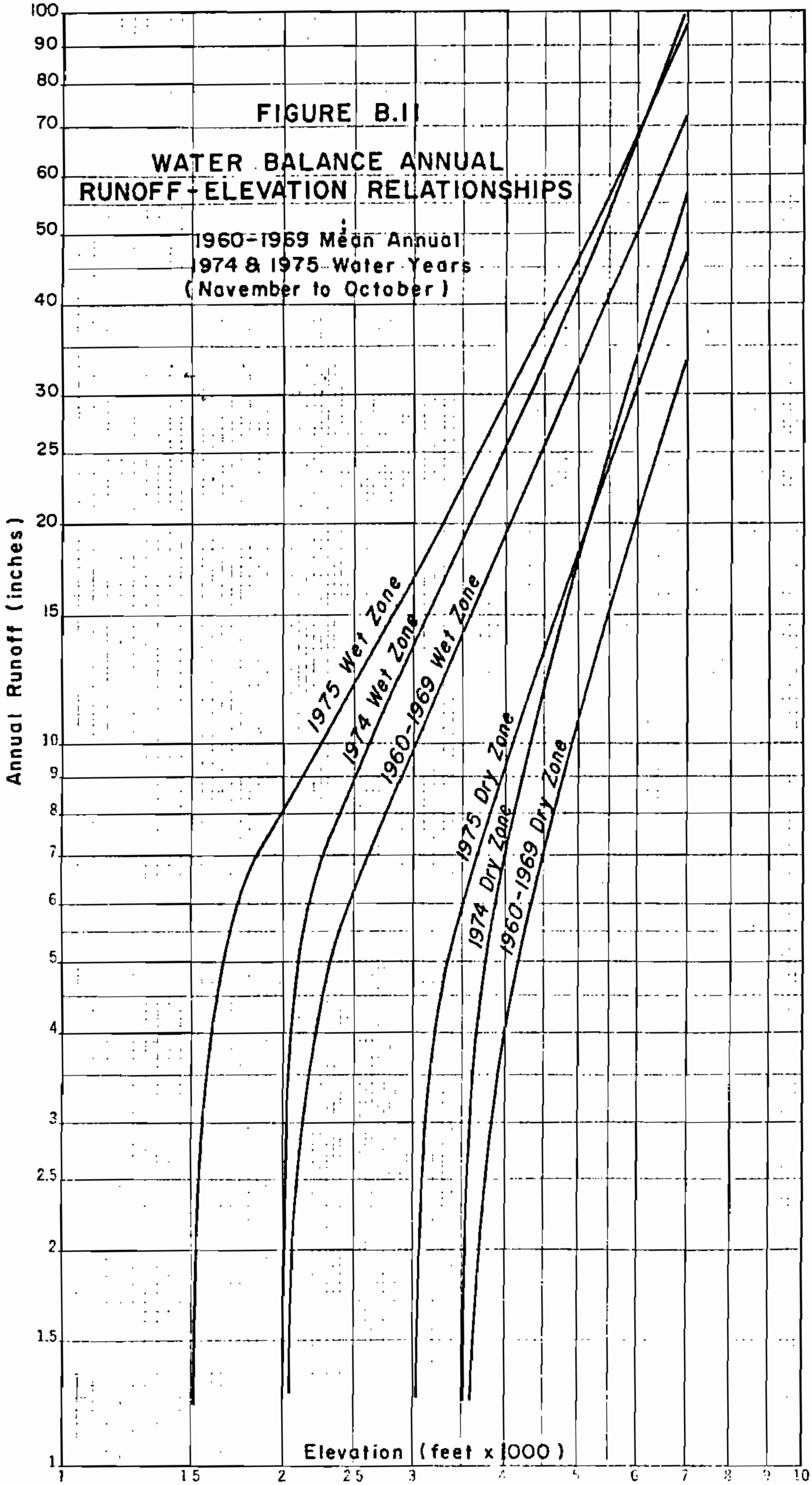
FIGURE B.11
WATER BALANCE ANNUAL
RUNOFF-ELEVATION RELATIONSHIPS
1960-1969 Mean Annual
1974 & 1975 Water Years
(November to October)
1975 Wet Zone
1974 Wet Zone
1960-1969 Wet Zone
1975 Dry Zone
1974 Dry Zone
1960-1969 Dry Zone
Annual Runoff (inches)
Elevation (feet x 1000)
100
90
80
70
60
50
40
30
25
20
15
10
9
8
7
6
5
4
3
2.5
2
1.5
1
1.5
2
2.5
3
6
7
10

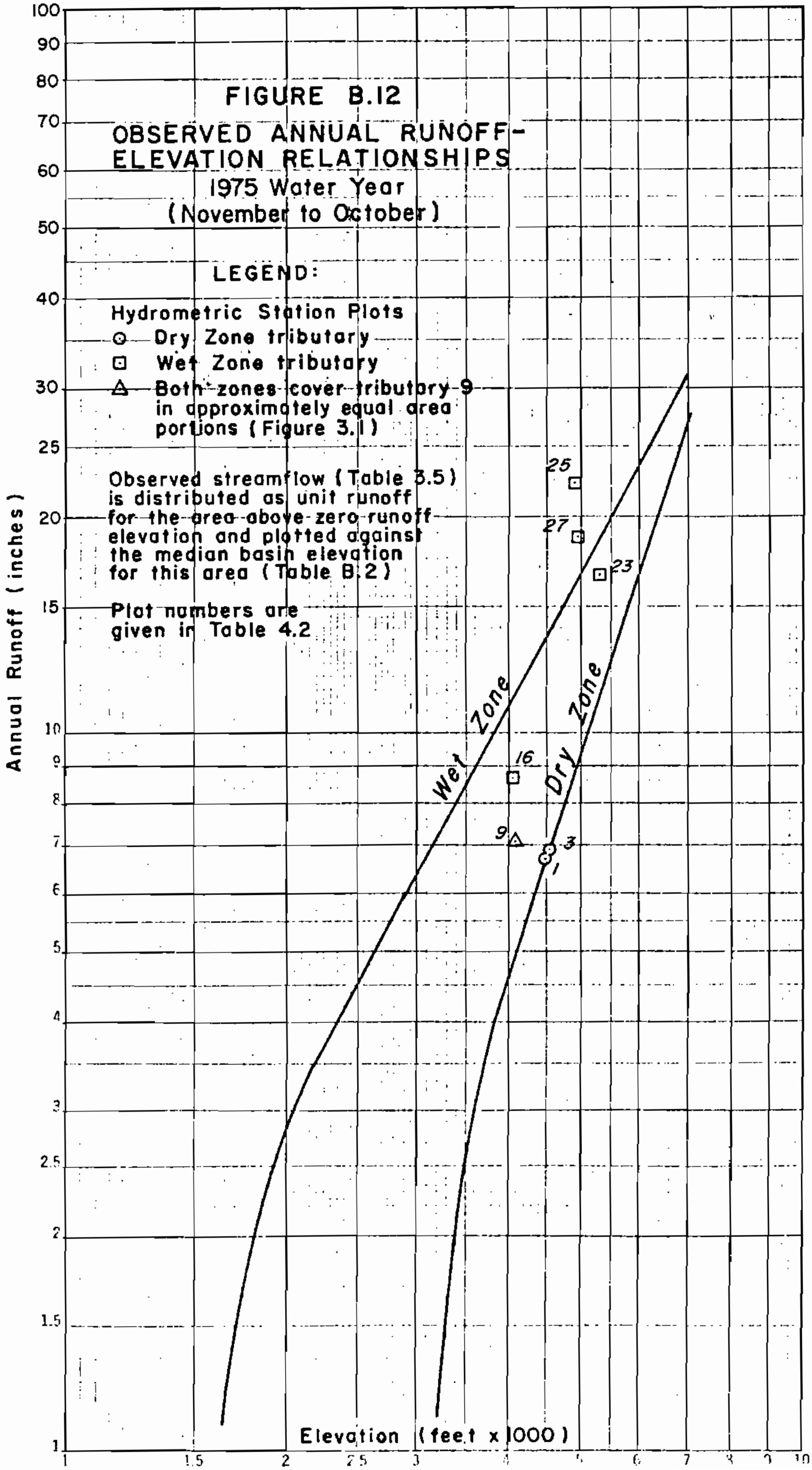
FIGURE B.12
OBSERVED ANNUAL RUNOFF-ELEVATION RELATIONSHIPS
1975 Water Year
(November to October)
LEGEND:
Hydrometric Station Plots
⊙ Dry Zone tributary
⊡ Wet Zone tributary
△ Both zones cover tributary 9 in approximately equal area portions (Figure 3.1)
Observed streamflow (Table 3.5) is distributed as unit runoff for the area above zero runoff elevation and plotted against the median basin elevation for this area (Table B.2)
Plot numbers are given in Table 4.2
Wet Zone
Dry Zone
25
27
23
16
9
3
1
Annual Runoff (inches)
Elevation (feet x 1000)
100
90
80
70
60
50
40
30
25
20
15
10
9
8
7
6
5
4
3
2.5
2
1.5
1
1.5
2
2.5
3
4
5
6
7
8
9
10

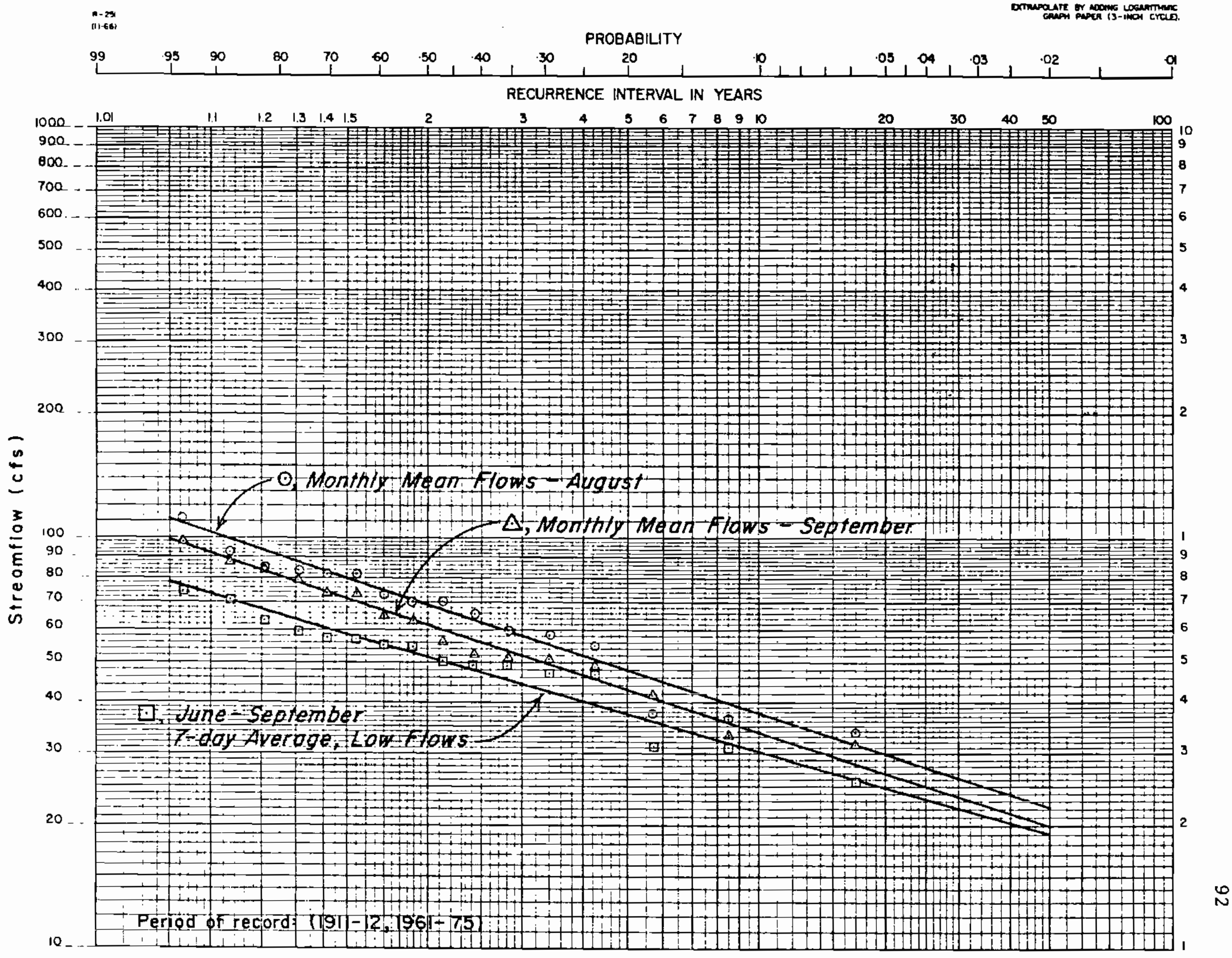

FIGURE B.13 LOW FLOW FREQUENCY CURVES
SALMON RIVER AT SALMON ARM (8LE021)

APPENDIX C

FISHERY STATION HYDRAULIC CHARACTERISTICS

TABLE C.1 FISHERY STATION HYDRAULIC CHARACTERISTICS

GAUGE HEIGHT* (ft.)	LOCAL ELEVATION (ft.)	HYDRAULIC MEAN ELEVATION (ft.)	CROSS SECTIONAL AREA (ft.^{2})	WETTED PERIMETER (ft.)	CHANNEL WIDTH (ft.)
		Station: F1			
0.4	90.8	0.1	0.2	1.8	1.7
0.4	91.0	0.2	0.7	3.8	3.6
0.4	91.4	0.3	3.1	9.2	9.0
0.8	92.4	0.5	22.0	42.0	41.5
1.5	92.8	0.7	43.0	63.4	62.8
1.7	92.9	0.8	49.3	63.9	63.1
2.1	93.2	1.0	68.4	65.2	64.3
2.6	93.6	1.4	94.4	67.0	65.9
2.7	93.7	1.5	101.1	67.4	66.3
3.0	94.0	1.8	121.1	68.6	67.3
3.4	94.4	2.1	148.3	70.1	68.5
		Station: F2			
	91.0	0.1	0.5	3.9	3.8
	91.2	0.2	1.5	6.4	6.3
	91.4	0.3	3.0	8.9	8.6
12.0	92.1	0.5	13.7	27.4	26.9
11.5	92.5	0.7	28.5	40.7	40.1
11.3	92.7	0.8	37.2	47.6	46.9
11.0	93.0	1.0	51.4	49.0	48.1
10.8	93.4	1.4	71.0	50.6	49.4
10.7	93.5	1.5	75.9	50.8	49.5
	93.8	1.8	90.8	51.5	49.8
	94.2	2.1	110.8	52.4	50.2

*Gauge height is for the nearest gauge, therefore, may not correspond to local elevations taken at the fishery station pins.

TABLE C.1 FISHERY STATION HYDRAULIC CHARACTERISTICS (Contd.)

GAUGE HEIGHT* (ft.)	LOCAL ELEVATION (ft.)	HYDRAULIC MEAN ELEVATION (ft.)	CROSS SECTIONAL AREA (ft.^{2})	WETTED PERIMETER (ft.)	CHANNEL WIDTH (ft.)
		Station: F3			
0.5	88.4	0.1	0.8	5.8	5.8
0.5	88.6	0.2	2.5	10.5	10.4
0.6	88.8	0.4	4.7	12.1	11.9
0.9	89.1	0.5	8.6	17.1	16.8
1.2	89.4	0.7	15.2	22.6	22.2
1.4	89.6	0.8	19.8	24.6	24.0
1.6	89.8	1.0	24.8	25.6	24.9
1.9	90.4	1.4	40.5	28.5	27.5
2.3	91.0	1.5	67.6	46.1	44.4
2.5	91.4	1.8	85.5	47.2	45.1
2.7	91.8	2.1	103.7	48.4	46.0
		Station: F4			
14.5	1356.2	0.1	1.9	14.6	14.6
14.4	1356.6	0.4	10.4	29.1	29.0
14.1	1356.8	0.5	17.1	34.2	34.1
13.5	1357.2	0.8	32.2	41.9	41.8
13.5	1357.3	0.8	34.0	42.4	42.2
13.1	1357.6	1.1	49.6	45.4	45.1
12.7	1358.0	1.4	68.2	48.1	47.7
12.6	1358.1	1.5	73.0	48.8	48.4
12.3	1358.4	1.7	87.8	50.8	50.3
11.9	1358.8	2.1	108.2	52.6	51.8
		Station: F5			
0.3	93.8	0.1	0.2	1.4	1.3
0.4	94.2	0.2	1.2	5.7	5.5
0.8	95.0	0.5	19.1	38.1	37.7
1.0	95.1	0.6	24.0	40.1	39.7
1.2	95.3	0.7	31.0	42.3	41.8
1.4	95.4	0.8	36.5	43.5	43.0
1.6	95.6	1.0	45.1	44.3	43.7
2.0	96.0	1.4	62.9	45.9	45.1
2.2	96.2	1.5	71.9	46.6	45.6
2.3	96.4	1.7	81.1	47.3	46.1
2.8	96.8	2.1	99.8	48.5	47.0

TABLE C.1 FISHERY STATION HYDRAULIC CHARACTERISTICS (Contd.)

GAUGE HEIGHT* (ft.)	LOCAL ELEVATION (ft.)	HYDRAULIC MEAN ELEVATION (ft.)	CROSS SECTIONAL AREA ($ft.^2$)	WETTED PERIMETER (ft.)	CHANNEL WIDTH (ft.)
		Station: F6			
	95.8	0.1	1.4	13.6	13.5
	96.0	0.2	5.0	20.7	20.7
	96.2	0.4	9.5	24.6	24.5
	96.5	0.5	18.8	37.3	37.2
1.1	96.8	0.7	31.0	47.4	47.2
1.2	96.8	0.7	31.6	48.0	47.8
1.6	97.0	0.8	41.5	50.4	50.1
1.9	97.2	1.0	51.6	51.4	51.0
		Station: F7			
	97.0	0.1	2.4	27.6	27.5
	97.2	0.3	8.8	33.8	33.7
1.0	97.5	0.5	17.8	35.5	35.3
1.4	97.8	0.8	30.1	37.4	36.8
2.1	98.5	1.4	56.0	40.2	39.0
2.3	98.6	1.5	60.6	40.6	39.4
2.7	99.0	1.8	76.6	42.3	40.6
	99.4	2.1	93.1	43.9	41.9

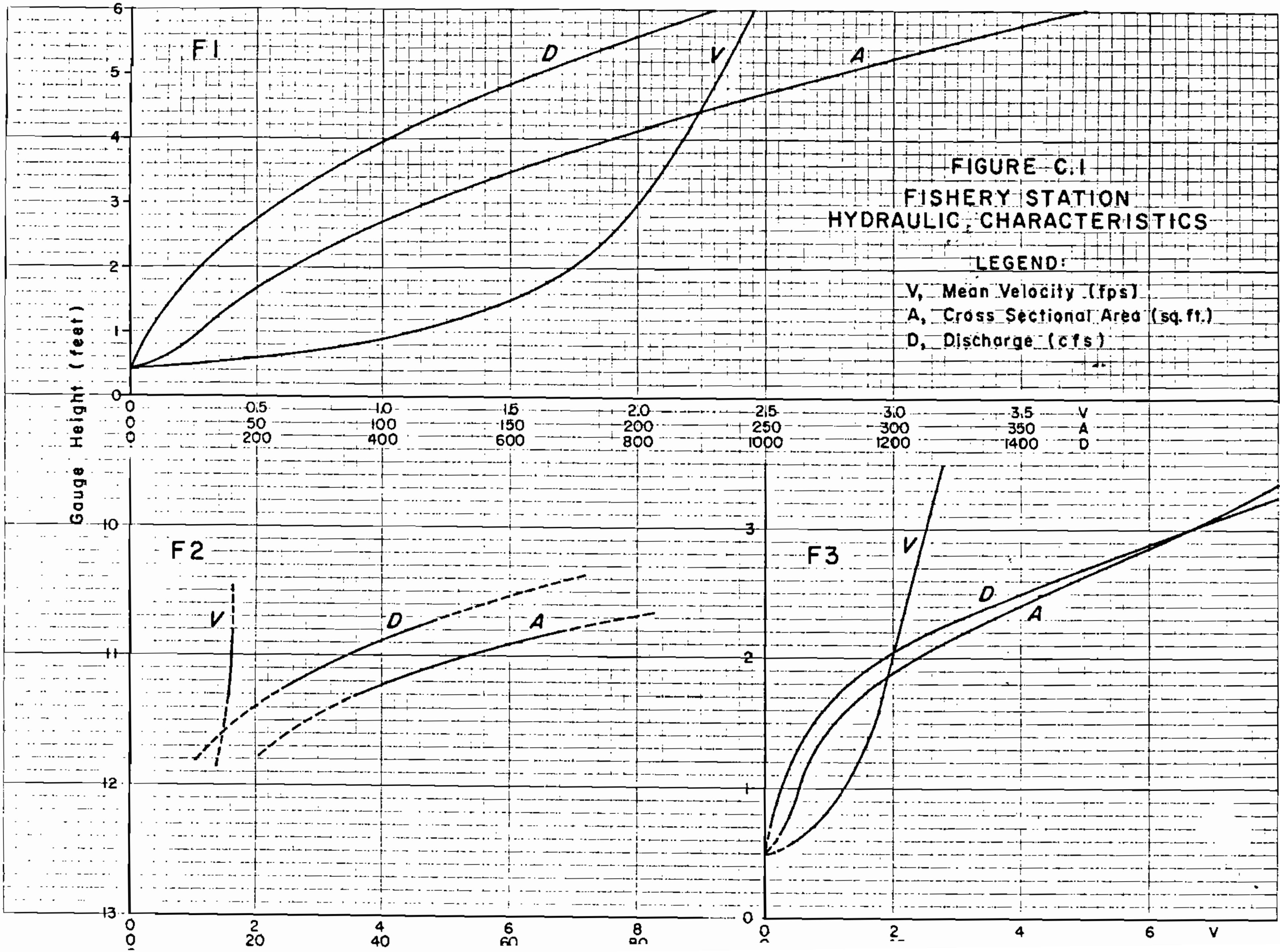
FIGURE C.1
FISHERY STATION
HYDRAULIC CHARACTERISTICS
LEGEND:
V, Mean Velocity (fps)
A, Cross Sectional Area (sq. ft.)
D, Discharge (cfs)
F1
F2
F3
Gauge Height (feet)
V A D
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 V
0 50 100 150 200 250 300 350 A
0 200 400 600 800 1000 1200 1400 D

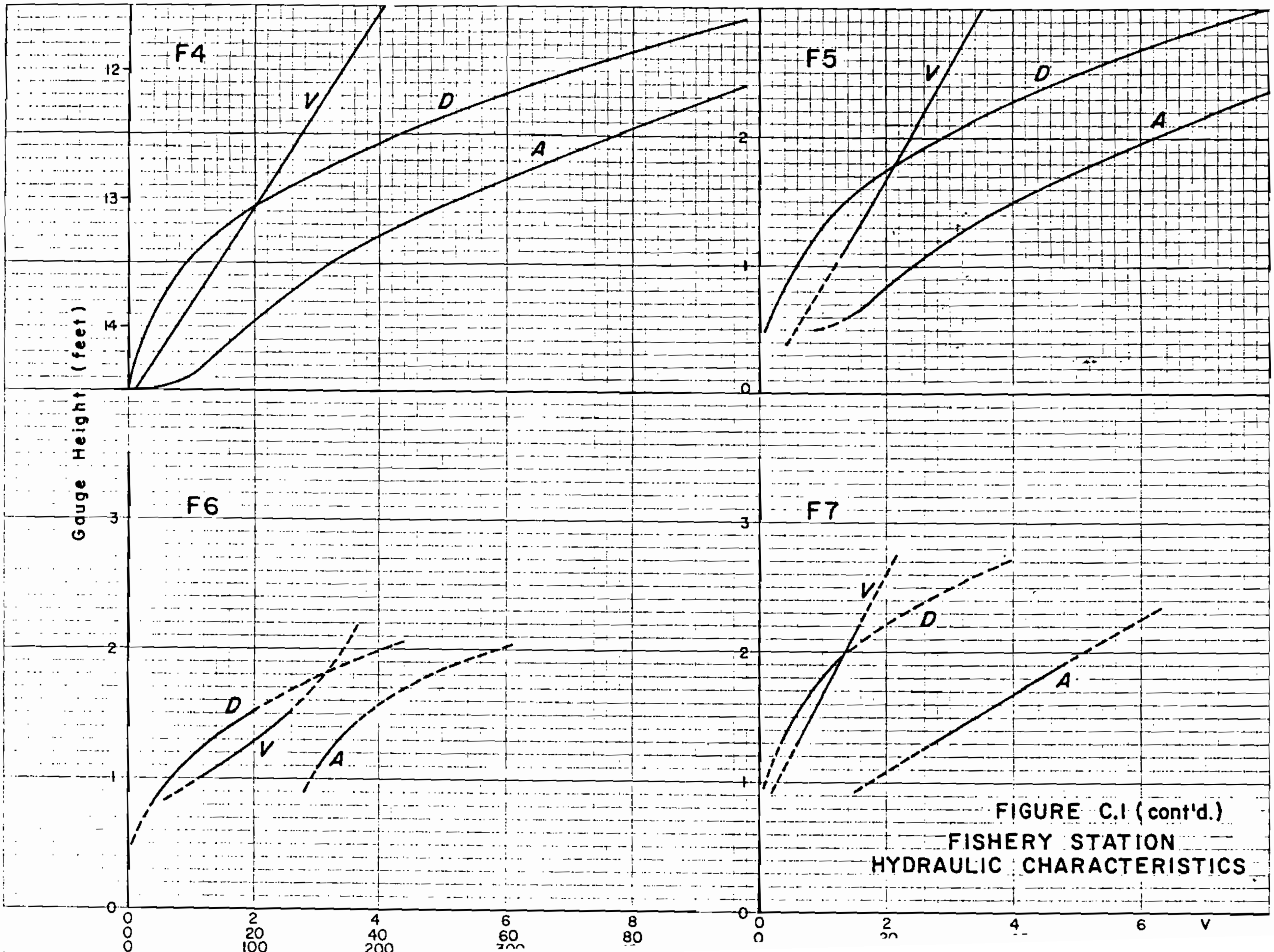

FIGURE C.I (cont'd.)
FISHERY STATION
HYDRAULIC CHARACTERISTICS

APPENDIX D

SALMON RIVER BASIN WATER LICENSES

TABLE D.1 SALMON RIVER BASIN WATER LICENSES

Listing in Upstream to Downstream Order

TRIBUTARY	DIVERSION POINT	PURPOSE	LICENSED DIVERSIONS *Non-Consumptive	Consumptive ac.-ft.	Consumptive g.p.d.	NUMBER OF LICENSES	LICENSE NUMBERS
Salmon R.	R.3740	Fish Cons.	10 cfs			1	CL36000
Gauging Stn.	8LE075	Sub-Total		0	0		
		Acc. Total		0	0		
Salmon R.	A.3740	Irrig.		184		2	FL6945, 3615
Rush Cr.	F.3740	Stor.	32			1	FL6409†
Rush Cr.	F.H.3740	Irrig.		121		1	FL6468
Salmon R.	S.Q.3740	Land Imp.	Whole Flow			1	CL31807
Munro Cr.	N.3739	Stor.	150			1	FL18984
Rush Cr.	Q.3739	Irrig.		50		1	FL18987
Munro Cr.	K.3739	Irrig.		150		1	FL18983
Greaves Cr.	P.3739	Stor.	158			3	CL30573, 30575, FL18986
Greaves Cr.	L.3740	Irrig.		158		2	FL18985, CL30574
Munro Cr.	B.3740	Irrig.		13		1	FL3614
Gauging Stn.	8LE063	Sub-Total		676	0		
		Acc. Total		676	0		
Goodwin Cr.	A.3739	Irrig.		58		1	FL3813
Goodwin Cr.	E.B.3739	Stor.	120			1	FL6410
Goodwin Cr.	F.3739	Irrig.		187		1	FL3714
Blackwell Cr.	M.3741	Stor.	1,500			1	CL41979
Twig Cr.	L.3736	Stor.	80			1	FL9492
Cain Cr.	G.3736	Irrig.		15		1	FL6363
Salmon R.	H.3736	Irrig.		25		1	FL6318
Salmon R.	F.3736	Irrig.		56		2	FL6298, 6768
Salmon R.	Q.3736	Land Imp.	Whole Flow			1	CL25690
Salmon R.	R.3736	Irrig.		600		1	CL33403
Fournier Spr.	T.3736	Dom.			1,000	1	CL38891
Gauging Stn.	8LE019	Sub-Total		941	1,000		
		Acc. Total		1,617	1,000		
Adelphi Cr.	N.3736	Irrig.		250		2	FL20590, CL33919
Salmon R.	S.3736	Irrig.		96		1	CL33310
Salmon R.	C.3736	Irrig.		991		8	FL5820, 6483, 13335, 13829, 13830, 13831, FL13833, CL33402
Salmon R.	A.3736	Irrig.		722		3	FL5819, 6485, 11238
Talbot Spr.	P.3736	Dom.			1,000	1	FL16879
Montewood Spr.	K.3736	Irrig.		5		1	FL5872
Percival Cr.	F.3735	Irrig., Dom.		15	11,000	3	FL8704, 6484, 17282
Val Spr.	QQ.3735	Dom.			1,000	1	FL20974
Dolly Spr.	UU.3735	Dom.			1,000	1	FL20599
Whitake Cr.	E.3734	Dom.			3,000	1	FL6407
Whitake Cr.	F.3734	Irrig.		40		1	FL15298
Spring	G.3734	Dom.			500	1	APP0309926
Gauging Stn.	8LE059	Sub-Total		2,119	17,500		
		Acc. Total		3,736	18,500		
Salmon R.	B.3735A	Irrig.		1,026		4	FL13838, 13839, 3703, 3706
Salmon R.	C.3735A	Irrig.		862		10	FL13834, 16214, 16215, 16216, 16217, 6748, FL18541, 13832, 18538, 18539
Salmon R.	A.3735A	Irrig.		812		7	FL13840, 13841, 13844, 13845, 13847, 13848, FL13849
Salmon R.	D3.3735A	Irrig.		507		4	FL13842, 18536, 5948, CL41212
Salmon R.	E3.3735A	Irrig.		359		1	FL11943
Salmon R.	Y.3735A	Irrig.		203		3	FL18540, CL42300, 42301
Salmon R.	HH.3735A	Irrig.		417		1	FL11942
Langton Br.	NN.3735	Dom.			500	1	FL19924
Slater Spr.	L3.3735	Dom.			500	1	CL42659
Berger Spr.	F3.3735	Dom.			500	1	CL38731
Meaker Spr.	WW.3735	Dom.			500	1	CL29358
Spring	H3.3735	Dom.			300	1	APP0310873
Alfred Spr.	G3.3735	Dom.			2,400	1	CL40765
Monte Lk.	LL.3735	Dom.			500	1	CL19245
Spring	J3.3735	Dom.			500	1	APP0310874
Monte Lk.	RR.3735	Dom.			1,000	1	FL20553
McLean Spr.	D3.3735	Dom.			500	1	CL36149
Spring	K3.3735	Dom.			500	1	APP0316119
Alma Spr.	YY.3735	Dom.			500	1	FL42548
Joyce Spr.	XX.3735	Dom.			500	1	FL42547
Gertrude Spr.	ZZ.3735	Dom.			1,000	1	CL42658
William Spr.	A3.3735	Dom.			1,000	1	FL42876
Dorothy Spr.	C3.3735	Irrig., Dom.		3	500	1	FL42549
Pasture Spr.	DD.3735	Dom.			500	1	FL10099
Pringle Cr.	B3.3735A	Dom.			1,000	1	CL32274
Rockwell Spr.	CC.3735A	Dom.			500	1	FL7982
Pringle Cr.	BB.3735A	Irrig.		342		2	FL10598, CL42466
Clemitson Cr.	E.3733	Irrig.		192		1	FL6070
Clemitson Cr.	K.3733	Dom.			4,000	3	FL14663, 20038, 20039
Hillside Spr.	L.3733	Irrig.		18		1	FL14686
Toye Spr.	Z.3733	Dom.			1,000	1	CL38890

*All quantities in ac.-ft. unless otherwise noted.
†Freshet - only, licenses are underlined.

TABLE D.1 SALMON RIVER BASIN WATER LICENSES (Contd.)

Listing in Upstream to Downstream Order

TRIBUTARY	DIVERSION POINT	PURPOSE	LICENSED DIVERSIONS *Non-Consumptive	Consumptive ac.-ft.	Consumptive g.p.d.	NUMBER OF LICENSES	LICENSE NUMBERS
Ingram Cr.	C.D.3734	Irrig.		30		1	FL9664
Ingram Cr.	H.3734	Stor.	420			1	APP0310616
Ingram Cr.	V.3733	Dom.			3,000	3	FL19855, 20519, CL33366
Ingram Cr.	D.3733	Irrig.		983		6	FL42545, 18546, 11941, 6068, 6069, 18562
Ingram Cr.	C.3733	Irrig.		396		6	FL42546, 43146, 43147, 43148, 43149, CL23039
Salmon R.	X.3733	Irrig.		180		1	CL41515
Salmon R.	CC.3733	Irrig.		105		1	CL41121
Salmon R.	W.3733	Irrig.		90		1	CL40286
Agnes Spring	BB.3733	Dom.			500	1	CL42299
Struthers Spr.	U.3733	Dom.			1,500	2	CL30237, APP0261546
Wilson Slough	R.3733	Land Imp., Irrig.	Whole Flow	280		2	CL29781, 29782
Seward Spr.	S.3733	Dom.			2,500	2	CL30005, 39664
Titus Spr.	N.3733	Irrig.		60		1	FL20040
Salmon R.	T.3733	Land Imp.	Whole Flow			1	CL30308
Currie Cr.	H.F.A.3733	Irrig.		60		1	FL11422
Currie Cr.	A.3733	Power, Irrig.	0.2 cfs	34		2	FL12019, 9074
Currie Cr.	Q.3733	Irrig., Dom.		40	1,000	1	CL23030
Falkland Cr.	G.3733	Irrig.		30		1	FL12037
Salmon R.	P3.3732	Irrig.		13		1	FL39358
Morris Br.	K.3737	Dom.			1,000	1	FL15753
Mail Cr.	C.B.3737	Irrig.		82		1	FL6912
Valentine Cr.	T.3737	Irrig.		50		1	CL37915
Valentine Cr.	G.3737	Irrig.		27		1	FL15004
Ivor Cr.	V.U.3737	Irrig.		18		1	FL15740
St. Laurent Cr.	R.3737	Irrig.		130		1	FL6976
Wilmot Cr.	82 L/12 E	Irrig., Dom.		20	1,000	1	CL42311
Bolean Cr.	A.3737	Irrig.		64		1	FL7566
Bolean Cr.	Q.3737	Irrig.		16		1	CL24469
Bolean Cr.	P.3737	Irrig.		72		1	FL18900
Bolean Cr.	S.3737	Land Imp.	Half Flow			1	FL18901
Bolean Cr.	P.N.3731	Irrig.		40		1	CL33917
Gulliver Spr.	J.3731	Dom.			1,000	1	CL30001
Blair Cr.	A.3731	Irrig., Dom.		77	2,000	1	FL5866
Blair Cr.	G.3731	Irrig.		21		1	FL7582
Banks Br.	L.3731	Irrig.		2		1	CL35097
Bolean Cr.	N.Q.3731	Irrig., Dom.		2	500	1	CL35357
Anna Spr.	AA.3733	Irrig.		3		1	CL39102
Anna Spr.	AA.3733	Irrig., Dom.		4	1,000	1	CL40764
Anna Spr.	M.3733	Irrig.		3		1	CL39101
Bolean Cr.	E4.3732	Irrig., Dom.		6	500	1	CL40285
Bolean Cr.	F4.3732	Dom.			500	1	CL40284
Bolean Cr.	G.3732	Irrig., Dom.		46	7,750	13	FL11700, 11705, 5808, 15905, 12660, 19682, FL17275, 17268, 18462, CL33308, 35720, APP0310546, 0317950
Bolean Cr.	Z.3732	Ind., Dom.	40,000 gpd		1,000	2	FL7224, 11799
Bolean Cr.	U4.3732	Irrig.		24		1	APP0322025
Bolean Cr.	F3.3732	Irrig.		16		1	CL27997
Bolean Cr.	MM.3732	Dom.			1,500	1	FL11241
Bolean Cr.	X4.3732	Irrig.		37		1	CL23041
Bolean Cr.	P4.3732	Irrig.		1		1	CL42656
Bolean Cr.	R3.3732	Land Imp.	Whole Flow			1	CL30443
Gauging Stn.	8LE020	Sub-Total		7,853	44,450		
		Acc. Total		11,589	62,950		
Creek	S4.3732	Dom.			500	1	APP0322314
Harrison Spr.	H4.3732	Dom.			1,000	1	APP0310414
Lynes Br.	Y3.3732	Irrig., Dom.		10	500	2	CL35908, 42654
Capel Spr.	M.3732	Irrig., Dom.		2	500	2	FL5806, CL38154
Salmon R.	L4.3732	Irrig.		140		1	CL42655
Salmon R.	U3.3732	Irrig.		80		1	CL33442
Moore Br.	S5.3732	Irrig.		38		1	FL17276
Kelly Spr.	D4.3732	Dom.			500	1	CL40007
Pearse Spr.	W3.3732	Irrig.		10		1	CL39100
Pearse Spr.	K.3732	Irrig., Dom.		7	500	2	FL8081, CL41844
Smith Spr.	EE.3732	Dom.			500	1	FL9484
Simpson Spr.	J3.3732	Dom.			1,000	2	FL40517, 40518
Falkland Spr.	F.D.3732	Irrig.		16		1	FL5878
Ferris Cr.	R.3732	Irrig.		22		1	FL5893
Ferris Cr.	H.3732	Irrig.		24		1	FL6063
Warren Cr.	B.3732	Irrig.		125		3	FL5879, 5877, 17284
Warren Cr.	CC.DD.3732	Irrig.		64		1	FL5882
Warren Cr.	L.3732	Irrig.		66		1	FL5810
Jay Spr.	J.3732	Irrig., Dom.		60	2,000	2	FL17293, CL31998
Falkland Spr.	D.E.3732	Irrig.		28		1	FL5880
Salmon R.	GG.3732	Irrig.		28		1	FL9863
Salmon R.	G3.3732	Irrig.		91		2	FL20597, 21299
Salmon R.	Q4.3732	Irrig.		54		1	FL39359
Salmon R.	C4.3732	Channel Imp.				1	APP459
Ess Br.	X3.3732	Irrig.		15		1	FL20598
Ess Spr.	S.JJ.3732	Dom.			3,500	2	FL6020, 6021
Johnson Spr.	M4.3732	Irrig., Dom.		20	1,000	2	CL33158, 40202

TABLE D.1 SALMON RIVER BASIN WATER LICENSES (Contd.)

Listing in Upstream to Downstream Order

TRIBUTARY	DIVERSION POINT	PURPOSE	LICENSED DIVERSIONS *Non-Consumptive	Consumptive ac.-ft.	Consumptive g.p.d.	NUMBER OF LICENSES	LICENSE NUMBERS
Salmon R.	R4.3732	Channel Imp.				1	APP390
Buchanan Cr.	N3.3732	Irrig., Dom.		24	1,000	1	FL40519
Points Cr.	E3.LL.3732	Irrig., Dom.		15	1,000	2	FL18281, CL33258
Salmon R.	N4.3732	Channel Imp.				1	APP625
Salmon R.	K3.3732	Irrig.		19		1	FL21405
Clear Br.	RR.3732	Dom.			500	1	FL14299
Dear Spr.	QQ.3732	Irrig.		8		1	FL14299
Ferguson Spr.	BB.3732	Dom.			500	1	FL6026
Salmon R.	Y.3732	Irrig.		7		1	FL6067
Gillis Br.	M3.3732	Dom.			1,000	1	CL27935
Gillis Br.	H3.3732	Irrig., Dom.		20	500	1	CL27934
Neal Spr.	D3.3732	Dom.			1,000	1	FL20712
Salmon R.	G4.3732	Irrig., Dom.		166	500	2	FL40855, CL40763
Salmon R.	AA.3732	Irrig.		12		1	FL5873
Bolean Cr.	82 L/12 E	Irrig.		9		1	FL9959
Bolean Cr.	82 L/12 E	Irrig.		78		1	FL7536
Creek	82 L/5 E	Irrig., Dom.		60	1,000	1	APP0317837
Bishop Cr.	L3.3732	Irrig.		40		1	CL27933
Archie Spr.	X.3732	Dom.			1,000	1	FL6058
Salmon R.	V4.3732	Dom.			10,000	1	CL42298
Salmon R.	UU.3732	Irrig., Ind.		97	15,000	3	FL42544, CL40462, 29904
Salmon R.	TT.3732	Irrig.		100		1	FL20560
Salmon R.	A5.R4.3732	Irrig., Dom.		20	500	2	CL43205, 43206
Gauging Stn.	8LE061	Sub-Total		1,575	45,000		
		Acc. Total		13,164	107,950		
Salmon R.	B3.C3.3732	Irrig.		27		1	FL9862
Spring	V.3738	Irrig., Dom.			50	1	APP0322058
Moczorodynski Spr.	T.3738	Dom.			1,000	1	CL37050
Hiltz Br.	S.3738	Dom.			500	1	CL36243
Leo Br.	R.3738	Irrig., Dom.		10	1,000	2	FL15283, 19980
Leo Br.	Q.3738	Irrig., Dom.		1	1,000	1	FL15326
Culling Br.	N.3738	Irrig.		25		2	CL38603, 38604
Culling Br.	W.3738	Dom.			1,000	1	FL15235
Elsom Spr.	P.3738	Irrig., Dom.		5	1,000	2	FL42967, CL40775
Herb Br.	G.3738	Dom.			500	1	FL16159
Hoath Br.	J.3738	Irrig., Dom.		90	500	2	CL25538, 40577
Evelyn Br.	F.3738	Dom.			1,000	1	FL15208
Bereti Spr.	M.3738	Dom.			1,500	1	CL39572
McRae Br.	H.3738	Dom.			1,000	1	CL27261
Salmon R.	A3.3732	Irrig.		310		1	CL39571
Salmon R.	T4.3732	Irrig.		30		1	APP0322767
Salmon R.	T3.3730	Irrig.		60		1	CL37008
Salmon R.	E3.D3.3730	Irrig.		130		1	CL30571
Salmon R.	P3.3730	Channel Imp.				1	APP255
Salmon R.	N3.3730	Irrig.		50		1	FL21581
Keith Spr.	F3.3730	Irrig., Dom.		60	1,000	1	CL29780
Francis Spr.	M3.3730	Irrig.		220		1	CL37860
Salmon R.	U3.ZZ.3730	Irrig.		140		2	FL21401, CL37009
Salmon R.	QQ.B3.3730	Irrig.		88		2	FL12898, 18087
Salmon R.	B3.3730	Irrig.		45		1	CL27197
Salmon R.	XX.3730	Irrig., Dom.		30	1,000	1	CL26747
Salmon R.	CC.3730	Irrig.		50		1	CL23918
McAchaney Cr.	F.G.3730	Irrig.		74		1	FL7021
Salmon R.	F4.G4.B.3730	Irrig.		168		5	FL6066, 9181, 9182, CL37463, 43198
Schweb Spr.	A3.3730	Dom.			500	1	CL27936
Salmon R.	U.3730	Irrig.		60		2	FL9275, 16985
Salmon R.	KK.3730	Irrig.		75		1	FL15515
Salmon R.	C4.3730	Irrig.		9		1	APP0322398
Salmon R.	A4.3730	Channel Imp.				1	APP624
Salmon R.	R.PP.3730	Irrig.		15		2	FL21439, 16986
Salmon R.	WW.3730	Irrig.		185		3	CL29098, 34685, 37858
Salmon R.	SS.3730	Irrig.		48		4	FL17520, 17521, 20998, CL34684
Salmon R.	Z3.3730	Irrig.		60		1	CL39099
Barrett Spr.	D.3730	Dom.			2,000	1	FL6027
Gauging Stn.	8LE065	Sub-Total		2,065	14,550		
	8LE805	Acc. Total		15,229	122,500		
Salmon R.	V3.3730	Irrig.		80		1	CL49006
Salmon R.	TT.3730	Irrig.		42		2	FL17522, 17523
Salmon R.	UU.3730	Irrig.		30		1	FL7445
Needoba Spr.	W3.3730	Irrig.		60		1	CL37859
Salmon R.	J3.3730	Irrig.		140		1	CL31437
Salmon R.	L3.3730	Irrig.		71		3	FL39568, 39569, 39570
Salmon R.	K3.3730	Irrig.		78		3	FL39195, 39196, 39197
Gauging Stn.	8LE097	Sub-Total		501	-		
		Acc. Total		15,730	122,500		
Salmon R.	S3.R3.3730	Irrig.		93		2	FL21097, CL35355
Salmon R.	D4.3730	Irrig.		11		2	CL42464, 42296
Gauging Stn.	8LE089	Sub-Total		101	-		
		Acc. Total		[illegible]	[illegible]		

TABLE D.1 SALMON RIVER BASIN WATER LICENSES (Contd.)
Listing in Upstream to Downstream Order

TRIBUTARY	DIVERSION POINT	PURPOSE	LICENSED DIVERSIONS			NUMBER OF LICENSES	LICENSE NUMBERS
			*Non-Consumptive	Consumptive			
				ac.-ft.	g.p.d.		
Salmon R.	JJ.UU.3730	Irrig.		67		2	CL42297, 42465
Salmon R.	SS.3728	Irrig.		20		1	FL15993
Salmon R.	K3.3728	Irrig.		13		1	CL37312
Fowler Cr.	VV.3728	Irrig.		116		3	FL6059, 6749, CL22472
Fowler Cr.	E.3728	Irrig.		96		2	FL6079, 15055
Fowler Cr.	WW.3728	Dom.			1,000	1	FL20319
Butchart Cr.	E3.3728	Irrig., Dom.		20	1,000	3	CL29967, 43199, 43207
Stephen Cr.	V3.3728	Dom.			500	1	CL37685
Stephen Cr.	F3.3728	Dom.			500	1	FL42966
Stephen Cr.	R.3728	Irrig.		16		1	FL7447
Salmon R.	G3.3728	Irrig.		14		1	FL42965
Salmon R.	Q3.3728	Irrig.		20		1	CL37313
Salmon R.	B3.3728	Irrig.		30		1	CL32984
Spa Cr.	GG.3728	Stor.		303		5	FL16955, 16956, 16958, 16927, CL25175
Spa Cr.	F.3728	Irrig.		182		3	FL5803, 9491, 16957
Spa Cr.	FF.QQ.3728	Irrig., Dom.		113	1,500	4	FL11764, 16926, 17314, CL25174
Ames Spr.	ZZ.3728	Dom.			500	1	CL28109
Willett Spr.	Y.3728	Dom.			2,000	1	FL16168
Symonds Spr.	R3.3728	Irrig., Dom.		20	1,000	1	CL37314
Salmon R.	G4.3728	Irrig.		6		1	CL42874
Salmon R.	F4.3728	Irrig.		14		1	CL42873
Summer Spr.	X3.3728	Dom.			1,000	1	CL37687
Salmon R.	XX.3728	Irrig.		30		1	CL23037
Allardice Cr.	B.3728	Dom.			1,000	1	FL6023
Salmon R.	D3.3728	Irrig.		40		1	CL30661
Salmon R.	N3.3728	Irrig.		60		1	CL34082
Salmon R.	K3.I3.3728	Irrig.		40		1	CL33866
Salmon R.	H4.3728	Irrig.		34		1	APP0322237
Andrew Br.	J3.3728	Dom.			2,000	4	CL33477, 36465, 42462, 42463
Andrew Br.	P3.3728	Dom.			500	1	CL34289
Haines Cr.	T.3728	Irrig., Dom.		29	1,000	3	FL21177, CL39858, 39859
Salmon R.	U3.3728	Irrig.		14		1	CL37462
Salmon R.	M3.3728	Irrig.		40		1	CL35040
Gauging Stn.	8LE098	Sub-Total		1,034	13,500		
		Acc. Total		16,[illegible]68	136,000		
Salmon R.	A3.3728	Irrig.		51		1	FL42066
Salmon R.	C3.3728	Irrig.		40		1	CL30660
Salmon R.	JJ.3728	Irrig.		6		1	FL12715
Salmon R.	B4.RR.3728	Irrig.		100		1	FL39360
Salmon R.	NN.3728	Irrig., Dom.		74	500	2	FL15996, CL18035
Salmon R.	N3.3726	Irrig.		5		1	CL37854
Salmon R.	H4.3726	Irrig.		30		1	CL40762
North Silver Cr.	H3.3726	Irrig., Dom.		70	1,000	1	CL33858
North Silver Cr.	U3.3726	Dom.			500	1	CL34196
Silver Cr.	A4.3726	Irrig., Dom.		129	10,500	25	FL15781, 21135, 14626, 17707, 17641, 17643, FL17642, CL40966, 40967, 40964, 40963, 40965, CL32459, 34571, 33806, 39193, 39098, 39192, CL39191, 39190, 39194, 42295, 42294, 42875, APP0322361
Silver Cr.	KK.3726	Dom.			2,000	1	FL14666
Silver Cr.	H.3726	Irrig.		21		1	FL12153
Silver Cr.	Y3.3726	Dom.			500	1	CL37856
Silver Cr.	K3.3726	Dom.			500	1	CL33805
Salmon R.	F4.3726	Channel Imp.				1	APP403
Salmon R.	ZZ.3726	Irrig.		100		2	FL21360, CL37857
Salmon R.	GG.3726	Irrig.		4		1	CL17971
Harold Br.	J4.3726	Dom.			500	1	APP0309003
Salmon R.	VV.3726	Irrig.		20		1	CL26659
Salmon R.	M3.3726	Irrig.		6		1	FL38981
Salmon R.	FF.3726	Irrig.		60		1	FL16140
Gauging Stn.	8LE090	Sub-Total		716	16,000		
		Acc. Total		17,584	152,000		
Salmon R.	E3.3726	Irrig.		60		1	FL18467
Salmon R.	T3.3726	Channel Imp.				1	APP238
Salmon R.	S3.3726	Irrig.		120		1	CL36463
Salmon R.	MM.3726	Irrig.		40		1	FL16090
Wall Cr.	C.3726	Irrig., Dom.		7	500	1	FL6016
Salmon R.	QQ.3726	Irrig.		65		2	FL21298, CL37310
Salmon R.	CC.3726	Irrig.		0		1	CL38152
Salmon R.	W4.UU.3726	Irrig.		34		2	CL34366, 42459
Salmon R.	K4.3726	Irrig.		2		1	CL38153
Salmon R.	U4.3726	Irrig.		10		1	CL42460
Salmon R.	T4.3726	Irrig.		10		1	CL42461
Mwat Cr.	Z.3726	Irrig.		10		1	FL9860
Grier Cr.	C4.3726	Irrig., Dom.		80	3,000	2	CL37460, 37461
Grier Cr.	G.3726	Irrig.		89		2	FL6556, CL23029
Salmon R.	A4.3726	Irrig.		65		1	CL37853
Salmon R.	G4.3726	Channel Imp.				1	APP404
Salmon R.	D4.3726	Irrig.		60		1	CL37855
Gauging Stn.	8LE088	Sub-Total		[illegible]	3,500		
		Acc. Total		[illegible]	[illegible]		

TABLE D.1 SALMON RIVER BASIN WATER LICENSES (Contd.)

Listing in Upstream to Downstream Order

TRIBUTARY	DIVERSION POINT	PURPOSE	LICENSED DIVERSIONS			NUMBER OF LICENSES	LICENSE NUMBERS
			*Non-Consumptive	Consumptive			
				ac.-ft.	g.p.d.		
Salmon R.	P4.3726	Irrig.		60		1	CL42653
Salmon R.	X3.3726	Irrig.		60		1	CL37511
Kernaghan Cr.	L4.3726	Dom.			4,500	7	CL41382, 41383, 41384, APP0322652, 0322653, APP0322654, 0322655
Kernaghan Cr.	JJ.3726	Irrig., Dom.		20	500	1	FL16880
Salmon R.	D3.3726	Irrig.		92		1	FL39189
Willis Br.	C3.3726	Dom.			750	1	FL21361
Wallensteen Lk.	S4.3726	Stor.	Whole Flow			1	APP0264382
Wallensteen Cr.	AA.3726	Dom.			500	1	FL9556
Wallensteen Cr.	F3.3726	Irrig., Dom.		220	1,000	2	FL43144, 43145
Salmon R.	NN.3726	Irrig.		120		1	FL15994
Rock Spr.	B.3726	Dom.			1,000	1	FL3171
Syme Cr.	V3.3726	Dom.			1,000	1	CL35475
Syme Cr.	XX.YY.3726	Irrig., Dom.		30	1,500	1	CL27437
Salmon R.	TT.3726	Irrig.		40		1	FL21400
Salmon R.	N4.M4.3726	Irrig.		30		1	CL40962
Gordon Cr.	G3.3726	Wwks.			40,000	1	CL30405
Gordon Cr.	R3.3726	Irrig.		90		2	CL31439, 33401
Gordon Cr.	BB.3726	Dom.			2,000	1	CL30854
Gordon Cr.	K3.3726	Irrig.		2		1	FL19297
Salmon R.	Q4.3726	Irrig.		50		1	APP0317477
Salmon R.	V6.3724	Irrig., Dom.		12	500	1	APP031712
Salmon R.	S5.3724	Irrig.		90		1	CL30240
Dolan Cr.	F4.3724B	Irrig., Dom.		20	500	1	FL20443
Salmon R.	K6.3724B	Irrig.		200		1	APP0317632
Salmon R.	G6.K6.3724B	Irrig.		99		2	CL33398, 43197
Salmon R.	V4.3724B	Irrig.		44		1	FL16924
Salmon R.	Y4.R4.3724B	Irrig.		128		2	FL16916, APP0322060
Salmon R.	A5.3724B	Irrig.		42		1	FL20473
Salmon R.	Z4.3724B	Irrig.		100		2	FL40516, CL41514
George Cr.	WW.3726	Dom.			1,000	1	CL27277
Rumball Cr.	SS.3726	Dom.			2,000	1	FL11590
Rumball Cr.	L3.3726	Wwks.			Whole Res. Flow	1	APP0270522
Rumball Cr.	J5.3724	Irrig.		20		1	CL27377
Rumball Cr.	XX.L.C6.3724	Irrig., Dom.		140	3,500	5	FL5867, 19683, 19207, 14044, CL31755
Rumball Cr.	V5.U5.R5.3724	Irrig.		50		1	CL29353
Teneycke Spr.	E6.3724	Irrig., Dom.		4	1,000	1	CL33212
Teneycke Spr.	H6.3724	Dom.			500	1	CL33213
Mouttell Cr.	X6.3724B	Dom.			500	1	APP0317638
Creek	V6.3724B	Dom.			1,000	1	APP0317029
Mouttell Cr.	WW.3724B	Irrig., Dom.		53	3,500	9	FL17265, 17266, 17267, 19296, 15372, CL34378, CL42891, 42872, APP0316160
Mouttell Cr.	J4.3724B	Irrig.		14		1	FL19406
Mouttell Cr.	C7.3724B	Irrig.		50		1	APP0322360
Mouttell Cr.	X.3724B	Dom.			500	1	FL5955
Mouttell Cr.	H.3724B	Irrig.		12		1	FL8495
Mouttell Cr.	X5.3724B	Irrig., Dom.		20	1,000	2	CL31354, 41843
Mouttell Cr.	H4.3724B	Dom.			200	1	CL19850
Mouttell Cr.	P4.Q4.3724B	Irrig.		25		1	FL16954
Salmon R.	A7.3724B	Irrig.		200		1	APP0322173
Salmon R.	D7.3724B	Irrig.		110		1	APP0322388
Salmon R.	Q6.3724B	Irrig.		184		2	CL40637, 43202
Salmon R.	B7.3724B	Irrig.		50		1	APP0322333
Salmon R.	A6.Z5.3724B	Irrig.		40		1	FL16882
Spring	E7.3724B	Dom.			500	1	APP0322742
Rockland Spr.	D4.3724B	Dom.			2,500	4	FL14235, CL37171, 37172, APP0322336
Blakes Cr.	W4.3724B	Dom.			500	1	FL18182
Blakes Cr.	HH.3724B	Dom.			1,000	1	FL4993
Palmer Cr.	QQ.3724	Irrig.		6		1	FL8319
Huntley Spr.	K5.L5.3724	Irrig.		15		1	CL27094
Goforth Spr.	T5.3724	Dom.			2,000	3	CL37191, 37192, 30090
Gleneden Br.	C5.3724	Dom.			1,000	1	FL18060
Gleneden Br.	H5.3724	Dom.			1,000	1	FL21398
Gleneden Br.	G5.3724	Irrig.		40		1	CL27262
Olson Br.	B5.3724	Dom.			1,000	1	FL18059
Gleneden Br.	F5.3724	Irrig.		36		1	CL27092
Palmer Cr.	E5.3724	Irrig., Dom.		54	2,000	1	CL27093
Palmer Cr.	F6.3724	Irrig.		20		1	CL33653
Mobbs Spr.	U4.3724	Dom.			500	1	FL21245
Huntley Br.	L4.S4.T4.3724	Irrig.		6		1	FL15172
Palmer Cr.	M4.3724B	Irrig., Dom., Wwks.		1	5,250	10	FL17441, 18388, 18389, 18390, 18391, 21399, CL28776, 28777, 27893, 29232
Palmer Cr.	T6.3724B	Dom.			1,500	2	CL40004, APP0310631
Palmer Cr.	W.3724B	Dom.			2,000	1	FL5944
Palmer Cr.	N3.3724B	Irrig.		82		2	FL5869, 16652
Palmer Cr.	Q5.3724B	Dom.			1,000	1	FL18159
Gauging Stn.	FLE021	Sub-Total		2,781	90,200		
		Acc. Total		21,017	245,700		
Salmon R.	N6.3724B	Irrig.		1		1	CL35718
		Grand Total		21,018	245,700		

APPENDIX E

PROPOSED ECONOMIC ANALYSIS OF WATER RESOURCE USE

PROPOSED ECONOMIC ANALYSIS OF WATER RESOURCE USE

A complete water resource study must include an economic analysis of the aggregate net value of each component within the overall system. This is especially important if there is a conflict of useage between a limited supply of resource as is the case with low flow water use in the Salmon River basin. Historically the water licensing system in British Columbia did not consider itself constrained to rates of water withdrawal and in their effects on other water use requirements due to an abundant supply of water. In most cases, no apparent conflict between water users existed and only total seasonal volume withdrawal was licensed (Section 8). Since the demand for irrigation water withdrawal is growing in the basin and conflicts with salmon spawning requirements, an economic evaluation of the net worth of each resource is necessary to consider each water use in its proper perspective.

An economic evaluation of component resource use would take the form of a benefit-cost analysis to arrive at the net benefit attributable to the resource. Each resource would have to be assessed in terms of its present value as well as its marginal increase in value when additional water is allocated to it.

The present total net benefit from agriculture, depending on irrigation in the Salmon River basin, is the benefit derived from farm production resulting from licensed irrigation water diverted minus that which would be realized without diverting for irrigation. Net benefit is defined as the benefit or total income minus total costs of production to the farm gate, including costs of irrigation and rental of water (which is currently a nominal yearly license fee). The net benefit of current agricultural production could easily be evaluated by a survey of animal production, irrigated acreages, types of crops produced, their market value, current costs of production, etc. Some subjective interpretation will have to be made, however, when evaluating net benefit of agricultural production without the use of irrigation water, and the survey would have to rely on farmer's or agronomist's opinion of what crops or animal production could result without irrigation diversion.

In a parallel context the total net benefit of fish production would be the net benefit of fisheries derived from a total natural flow state of the Salmon River minus that which would be realized with irrigation water diversion. Needless to say, this would be much more difficult than the agricultural economic evaluation, but certain data is available which would lend itself to this type of analysis. Yearly fish runs have been recorded from 1924 (Reference 11) and licensed water data and some hydrometric data are available. A "natural" state or magnitude of fish production may possibly be estimated, but the figures would remain hypothetical. The net benefit for fish production is defined as the total (e.g., wharf) income from the sale of raw fish by fishermen minus their cost of fishing.

The future economic value of each resource use will have to be evaluated in its marginal increase in value over its present value when an extra amount of resource is allocated and/or greater efficiency is introduced to the means of production. In the case of irrigation water useage a new assessment of actual water withdrawal will have to be made since experience has shown that the rate and quantity of water withdrawn does not necessarily correspond to the total quantity licensed. A survey would have to be conducted to determine what is actually withdrawn. Irrigation crop requirements are known (Reference 6) and, if strictly interpreted, an accurate figure of current water demand (covered by licensed total quantities) could be calculated. From the total water available (after discounting fishery spawning requirements) the amount of water available for further licensing could be ascertained. Comparatively, there would be no marginal increase in fish production since a residual amount of water would be allocated to satisfy spawning requirements and the number of spawners would depend on other factors than volumes of water. There may be an increase over present spawning numbers, but it would be difficult to isolate this increase due to increased low flows alone.

The assessment of future allocation of water for irrigation will have to include a program of greater efficiency to establish the equitable distribution of water resources for various users. A strict irrigation practise